APPENDIX I

TECHNICAL MEMORANDUM #5

City-wide Sanitary Servicing Master Plan Update: FINAL Technical Memorandum 5

Task 5: Flow Monitoring and Infiltration & Inflow

Prepared for:
City of Waterloo

Prepared by:
Stantec Consulting Ltd.

1611 11191

August 20, 2015

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Sign-off Sheet

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Prepared by
(signatures)

Jennifer Hale, EIT **and** **David Eadie, P.Eng.**

Reviewed by
(signature)

QA/QC: John C Lam, P.Eng.

Reviewed by
(signature)

Project Manager: Leigh McDermott, M.E.Sc., P.Eng.

Accepted by _____
(signature)

City of Waterloo Project Manager: Jakub Cyperling, C.E.T.

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1.0 BACKGROUND

The City of Waterloo (City) has retained Stantec Consulting Ltd. (Stantec) to complete the Waterloo Sanitary Servicing Master Plan (Master Plan). The purpose of the Master Plan update is to account for increases in population and employment growth projections up to a planning horizon of 2031. Priority and strategic projects will be evaluated to allow the system to continue to operate efficiently and effectively implement best management practices, and optimize staging of the sanitary capital program.

The following tasks form the basis of the Master Plan:

- Task 1: GIS Sanitary Quality Control and Field Verification
- Task 2: Hydraulic Needs Assessment
- Task 3: Hydraulic Model Benefit/Cost Analysis
- Task 4: Hydraulic Model Development, Training, and Implementation
- Task 5: Flow Monitoring and Inflow/Infiltration
- Task 6: Public Consultation
- Task 7: Master Plan

Task 5 is intended to summarize the historic flow monitoring data and infiltration/inflow (I/I) results of the past, alongside the recent flow monitoring data for 2013. In addition, Task 5 will be used to help identify strategic flow monitoring locations to assist both model calibration and I/I characteristics.

2.0 HISTORIC FLOW MONITORING AND I/I

Several studies have been undertaken in the past regarding the collection system overall performance. These reports include:

- Sanitary Sewer Flow Monitoring Program - 1993 (Gore & Storrie, 1994)
- Sanitary Sewer Flow Monitoring Program - 1998, Eastbridge on the Grand and Upper Beechwood Subdivisions (CRA, 1999)
- City Wide Sanitary Sewer System Master Plan Update (EarthTech, 2002)
- Clair Sewershed I/I Pilot Project (Stantec, 2012)

This section consolidates the general findings of these studies, with the goal of generalizing the dry and wet weather results into characteristics for sewersheds across the City. This information will be used to compare against the results of the recent flow monitoring campaign to confirm historic findings and/or identify changes in system performance.

2.1 REPORT REVIEW

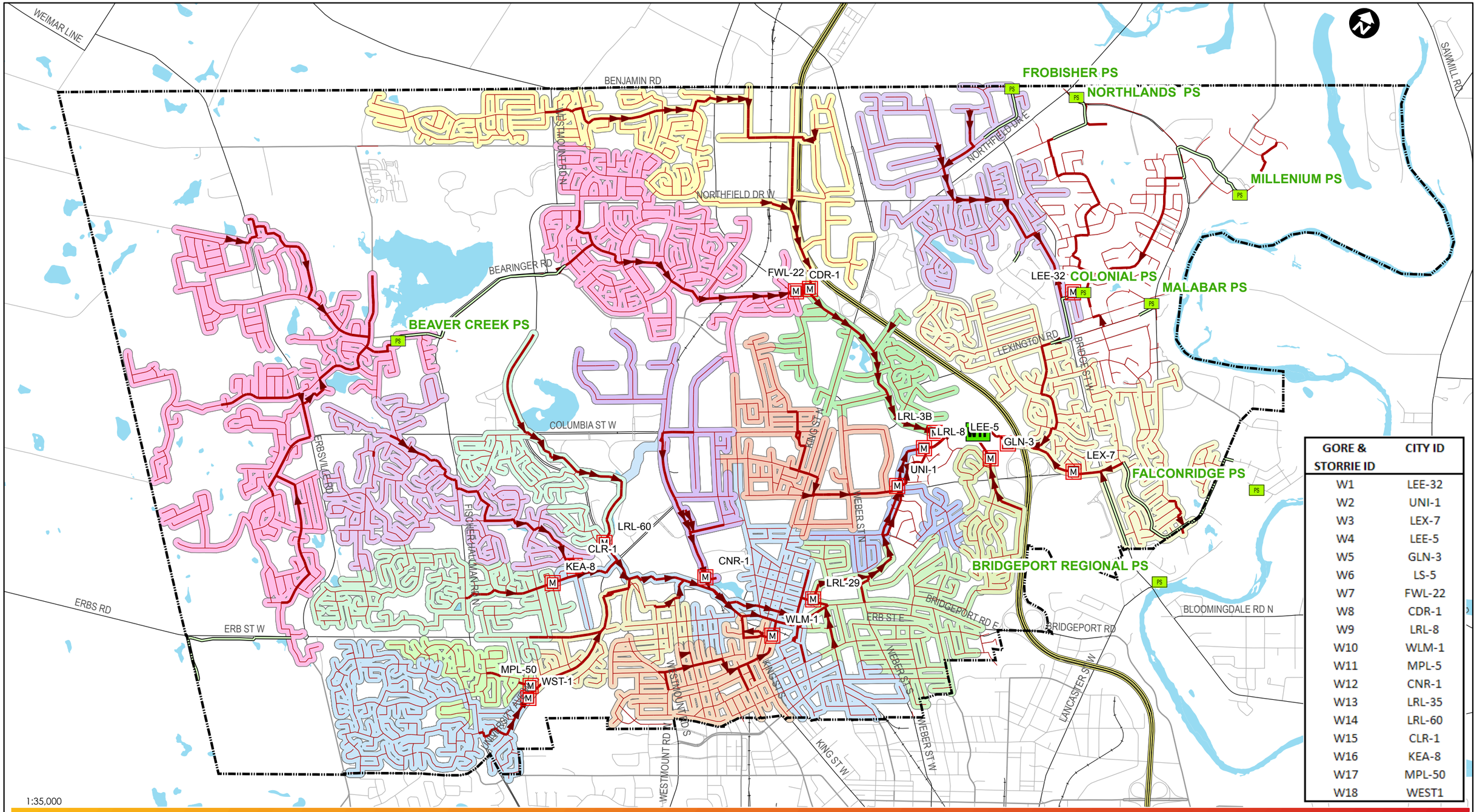
2.1.1 Report on the Sanitary Sewer Flow Monitoring Program - 1993 (Gore & Storrie, 1994)

In 1993, the City had estimated that 40% of sewage flows were from extraneous sources. In response, the City conducted an I/I study to identify these sources and regain capacity within the sewage collection network.

A total of 18 flow monitoring stations were installed and operated for a period of seven (7) months beginning in mid-March, 1993. Nine (9) rainfall events from two (2) rain gauges were used in conjunction with the flow monitoring data to conduct analysis and estimate dry weather infiltration (baseflow), and wet weather inflow and infiltration. The monitor locations and upstream catchments are depicted in Figure 1.

Data from two (2) rain gauges were used for this study. One (1) rain gauge was located at the Grand River Conservation Authority's Laurel Creek Conservation Area (GRCA), and the other at the Regional Municipality of Waterloo Sewage Treatment Plant (STP).

The estimated extraneous flows were quantified in relation to the City of Waterloo's design allowance of 12,960 L/ha/d (0.15 L/s/ha) for dry weather I/I, and no allowance for wet weather I/I. The typical dry weather flows, maximum wet weather flows, and total observed I/I have been back calculated using the given percentages of the design base infiltration. These values are shown in Tables 1 to 3.



GORE & STORRIE ID	CITY ID
W1	LEE-32
W2	UNI-1
W3	LEX-7
W4	LEE-5
W5	GLN-3
W6	LS-5
W7	FWL-22
W8	CDR-1
W9	LRL-8
W10	WLM-1
W11	MPL-5
W12	CNR-1
W13	LRL-35
W14	LRL-60
W15	CLR-1
W16	KEA-8
W17	MPL-50
W18	WEST1

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Legend

Transportation Network
- Arterial
- Collector
- Highway
- Local
- CityBoundary
- Water Body
- Forcemain
- WTP Wastewater Treatment Plant

Sanitary Sewers
- Local Sewers
- Trunk Sewers
- M Flow Monitor Locations

Stantec
Stantec Consulting Ltd.
49 Frederick Street
Kitchener, Ontario, Canada
N2H 6M7
Tel: (519) 579-4410
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Figure No. FIG-1

Title **GORE AND STORRIE FLOW MONITORING LOCATIONS AND COVERAGE (1994)**

Client/Project City of Waterloo
Waterloo Sanitary Master Plan

Table 1: G&S 1994 - Typical Dry Weather Base Infiltration

Gore & Storrie ID	MH ID	Sewershed	Percentage of Allowable Base Infiltration[1]			Range of I/I flows (L/s/ha)		
W10	**WLM-1**	William Trunk	75%	to	100%	0.113	to	0.150
W15	**CLR-1**	Clair Trunk	200%	to	300%	0.300	to	0.450
All Other Sewersheds			0%	to	75%	0.000	to	0.113

Note 1: Allowable infiltration is defined by the base infiltration rate of 0.15 L/s/ha based on the City of Waterloo Design Guidelines.

Table 2: G&S 1994 - Maximum Observed I/I

Gore & Storrie ID	MH ID	Sewershed	Percentage of Allowable Base Infiltration[1]			Range of I/I flows (L/s/ha)		
W9	**LRL-8**	Laurel Trunk @ STP	100%	to	150%	0.150	to	0.225
W18	**WEST1**	Westvale Trunk	100%	to	150%	0.150	to	0.225
W5	**GLN-3**	Glenridge Trunk @ STP	150%	to	200%	0.225	to	0.300
W2	**UNI-1**	University Trunk	200%	to	250%	0.300	to	0.375
W8	**CDR-1**	Cedar Trunk	250%	to	300%	0.375	to	0.450
W10	**WLM-1**	William Trunk	300%	to	350%	0.450	to	0.525
W15	**CLR-1**	Clair Trunk	300%	to	350%	0.450	to	0.525
All Other Sewersheds			0%	to	100%	0.000	to	0.000

Note 1: Allowable infiltration is defined by the base infiltration rate of 0.15 L/s/ha based on the City of Waterloo Design Guidelines.

Table 3: G&S 1994 - Typical Observed I/I

Gore & Storrie ID	MH ID	Sewershed	Percentage of Allowable Base Infiltration[1]			Range of I/I flows (L/s/ha)		
W2	**UNI-1**	University Trunk	100%	to	150%	0.150	to	0.225
W10	**WLM-1**	William Trunk	100%	to	150%	0.150	to	0.225
W8	**CDR-1**	Cedar Trunk	150%	to	200%	0.225	to	0.300
W15	**CLR-1**	Clair Trunk	250%	to	300%	0.375	to	0.450
All Other Sewersheds			0%	to	100%	0.000	to	0.150

Note 1: Allowable infiltration is defined by the base infiltration rate of 0.15 L/s/ha based on the City of Waterloo Design Guidelines.

Base infiltration rates are defined as the flow rates that would be found in the sanitary sewer system even if no wastewater was generated. The daily average minimum flowrate was calculated at each station as the minimum average occurring over a 2 hour interval between the times of 2:00 AM to 8:00 AM each day. The daily average baseflow infiltration rates were calculated as 85% of the daily average minimum flowrates. The daily average baseflow generation rates (L/s/ha) were calculated with reference to the total sewershed areas.

Areas W10 (WLM-1) and W15 (CLR-1) consistently exhibited wet weather extraneous flows at, or above, the design guidelines. Some areas exhibited higher infiltration rates during the spring, but dropped to acceptable levels through the remainder of the study period.

No conclusions could be drawn for areas W11 (MPL-5) and W13 (LRL-29) due to complications with establishing proper incremental drainage areas.

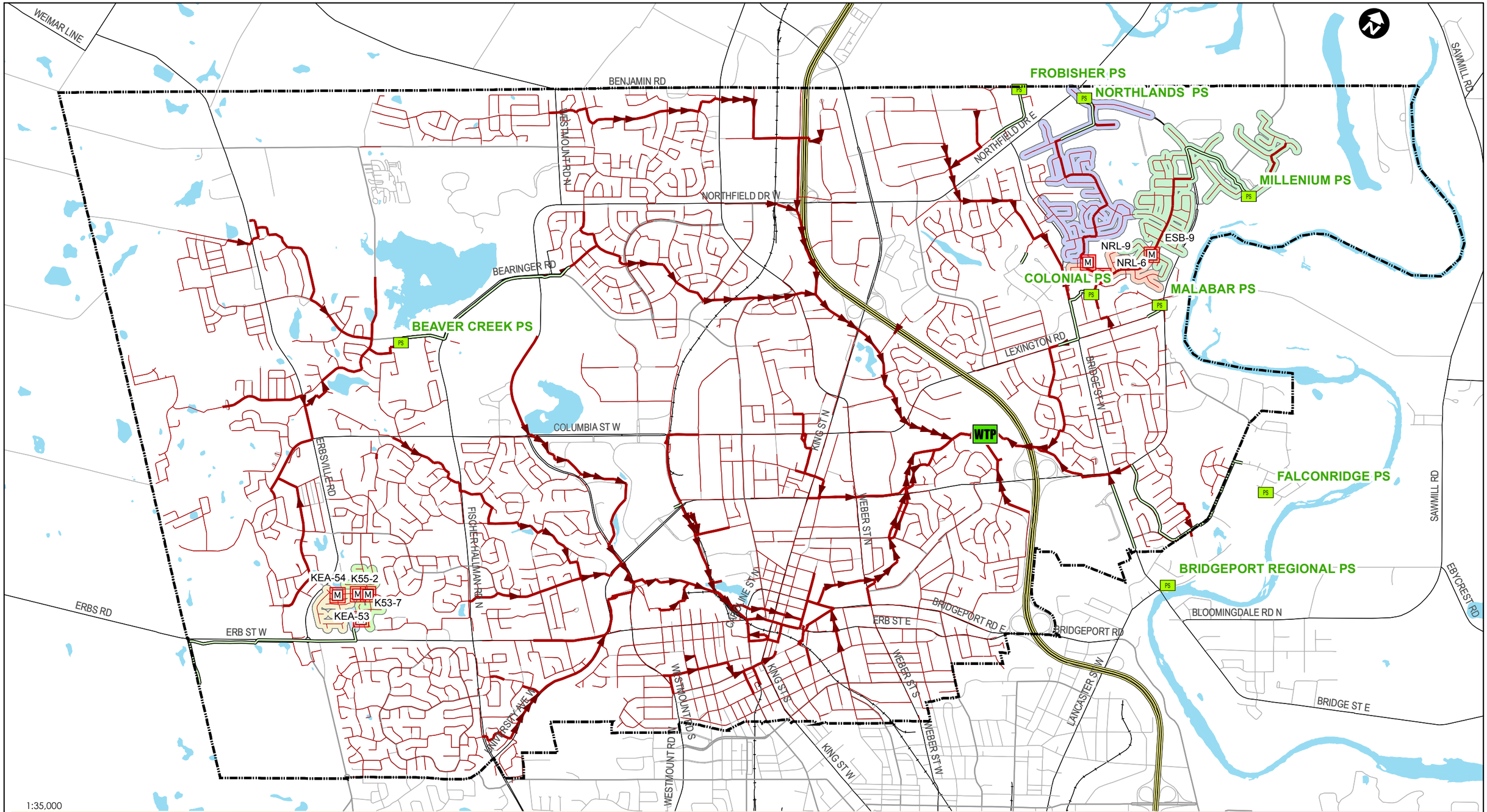
2.1.2 Sanitary Sewer Flow Monitoring Program - 1998, Eastbridge on the Grand and Upper Beechwood Subdivisions (CRA, 1999)

Conestoga Rovers & Associates was retained by Liqui Force Services to provide sanitary sewer flow monitoring services in the City to support the sanitary sewer evaluation program being undertaken by Liqui Force. The overall objective of the sanitary sewer rehabilitation program is the reduction and or elimination of unknown extraneous flows within the system. Two (2) specific study areas were identified including the Eastbridge on the Grand area (Area 1) and the Upper Beechwood / Erbsville Road area (Area 2). The monitor locations and upstream catchments are depicted in Figure 2.

Several sources of data were used in analyzing and validating the flow monitoring data, including the following:

- Sanitary sewer design data provided by the City Staff;
- Water consumption records provided by Waterloo North Hydro;
- Rainfall data provided by the University of Waterloo weather station;
- Results of smoke testing completed by Liqui Force; and
- Visual field observation.

Area 1: Eastbridge on the Grand - Four (4) monitors were installed within Area 1: NRL-9, ESB-9, NRL-6 (from NRL-7) and NRL-6 (from ESB-1). Flow monitor ESB-9 Eastbridge Boulevard at Wind Jammer Way was not functioning properly. The monitor malfunction was attributed to siltation interfering with the ultrasonic velocity measurement and the data obtained at this location was not considered suitable for further analysis.



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Stantec Consulting Ltd.
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- M Flow Monitor Locations

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Figure No. FIG-2

Title **CRA FLOW MONITOR LOCATIONS AND COVERAGE (1999)**

Client/Project City of Waterloo
Waterloo Sanitary Master Plan

The base infiltration (dry weather infiltration) was estimated as being the flows during the early morning. Wet weather flows were estimated using the difference between flows following a precipitation event and typical flows during dry weather. These flows are summarized in Table 4.

Table 4: CRA 1998 - Eastbridge Flow Monitoring Summary

Metric	NRL-9 Mayflower Street	NRL-6 (from NRL-7) Eastbridge Boulevard	NRL-6 (from ESB-1) Eastbridge Boulevard
Monitor Characteristics			
Duration of Monitoring	18-Jun-98 to 10-Aug-98	18-Jun-98 to 23-Nov-98	18-Jun-98 to 10-23-Nov-98
Number of Wet Weather Days	17	48	48
Total Area (ha)	78.8	106.6	106.6
Flows			
Average Dry Weather Flow (L/s/ha)	0.004	0.006	0.008
Total Measured Flow (L/s/ha)	0.014	0.023	0.029
Total Dry Weather I/I (L/s/ha)	0.000	0.005	0.009
Total Wet Weather I/I (L/s/ha)	0.003	0.001	0.001
Total I/I (L/s/ha)	0.003	0.006	0.010
Ratio of Wet Weather I/I to Total Measured Flow	20%	24%	34%

Monitor NRL-9 observed no base infiltration, and both NRL-6 monitors observed base infiltration values ranging from 0.005 L/s/ha to 0.009 L/s/ha. A lag in wet weather response is observed after rainfall events, which suggests that the most likely cause of extraneous flows is infiltration. Visual observations indicated leakage / seepage within maintenance-hole structures, accumulation of silt, other debris within the system.

During analysis, water consumption data was compared to the monitored average sewerage flows. Water consumption records do not approximate the observed sanitary flows, which further supports the conclusion that extraneous water is contributing to flows.

Area 2: Beechwood/Erbsville Road - In Area 2, the K53-7 Monitor at Sandbury Lane observes landfill leachate waste from the Erb Street Landfill in addition to domestic sanitary. The high I/I values within this catchment area is largely attributed to the landfill as leachate flows are particularly high during storm events.

Within this area, the generated sewage flows are within the original design parameters with the exception of peak leachate flows from the landfill in two (2) monitor locations (KEA-53 and K53-7). The exceedance of the design capacities can potentially cause surcharging. Significant dry weather infiltration was not observed in this area. Water consumption records closely approximated observed sanitary flows; and visual observations indicate quality construction and a watertight system. Peak flows coincide with storm events, indicating the presence of storm connections to the sanitary sewer system, as identified with smoke testing.

Table 5: CRA 1998 – Beechwood/Erbsville Flow Monitoring Summary

Metric	K55-2 Easement, Royal Beech Drive	KEA-54 Royal Beech Drive	K53-7 Sandbury Lane[2]	KEA-53 Royal Beech Drive at Beechwood Drive
Monitor Characteristics				
Duration of Monitoring	27-Apr-98 to 13-Aug-98	27-Apr-98 to 13-Aug-98	06-Jun-98 to 15-Jul-98	20-May-98 to 12-Aug-98
Number of Wet Weather Days	34	37	21	44
Total Area (ha)	13.4	15.9	2.7	34.7
Flows				
Average Dry Weather Flow (L/ha/d)	0.081	0.060	0.205	0.047
Total Measured Flow (L/s/ha)	0.231	0.157	0.514	0.095
Total Dry Weather I/I (L/s/ha)	0.000	0.000	0.000	0.000
Total Wet Weather I/I (L/s/ha)	0.013	0.008	0.149	0.001
Subtotal I/I (L/ha/d)	0.013	0.008	0.149	0.001
Leachate Flow[1] (L/s/ha)	-	-	0.347	-
Total I/I - with Leachate (L/s/ha)	0.013	0.008	0.496	0.001
% of Total Measured Flow	5.70%	5.03%	28.95%	65%

Note 1: Monitor K53-7 is located upstream of KEA-53. Therefore the wet weather flow from the K53-7 has been subtracted from that of KEA-53. The reported value is the difference between the wet weather flow for the two monitors in series.

Note 2: Landfill leachate is discharged into this catchment.

2.1.3 City Wide Sanitary Sewer System Master Plan Update (EarthTech, 2002)

In 2002, EarthTech completed a City Wide Sanitary Sewer System Master Plan Update. The Master Plan Update expands upon previous studies and investigations. The purpose of the study is to aid in decision making regarding infrastructure upgrades, and the development of a sanitary model.

Flow monitoring was conducted from March to November of 2000 at 13 locations. Earth Tech has reported theoretical dry weather flows and measured peak dry weather flows (DWF) for 26 locations. Although only 13 monitors were installed during this study, it is understood that additional flow monitoring information was derived from the previously mentioned historic reports. Figure 3 shows the locations of the monitors listed in Table 6. Although the EarthTech study included flow monitoring, the reported inflow and infiltration trends were based on the values from the Gore and Storrie report (1994).

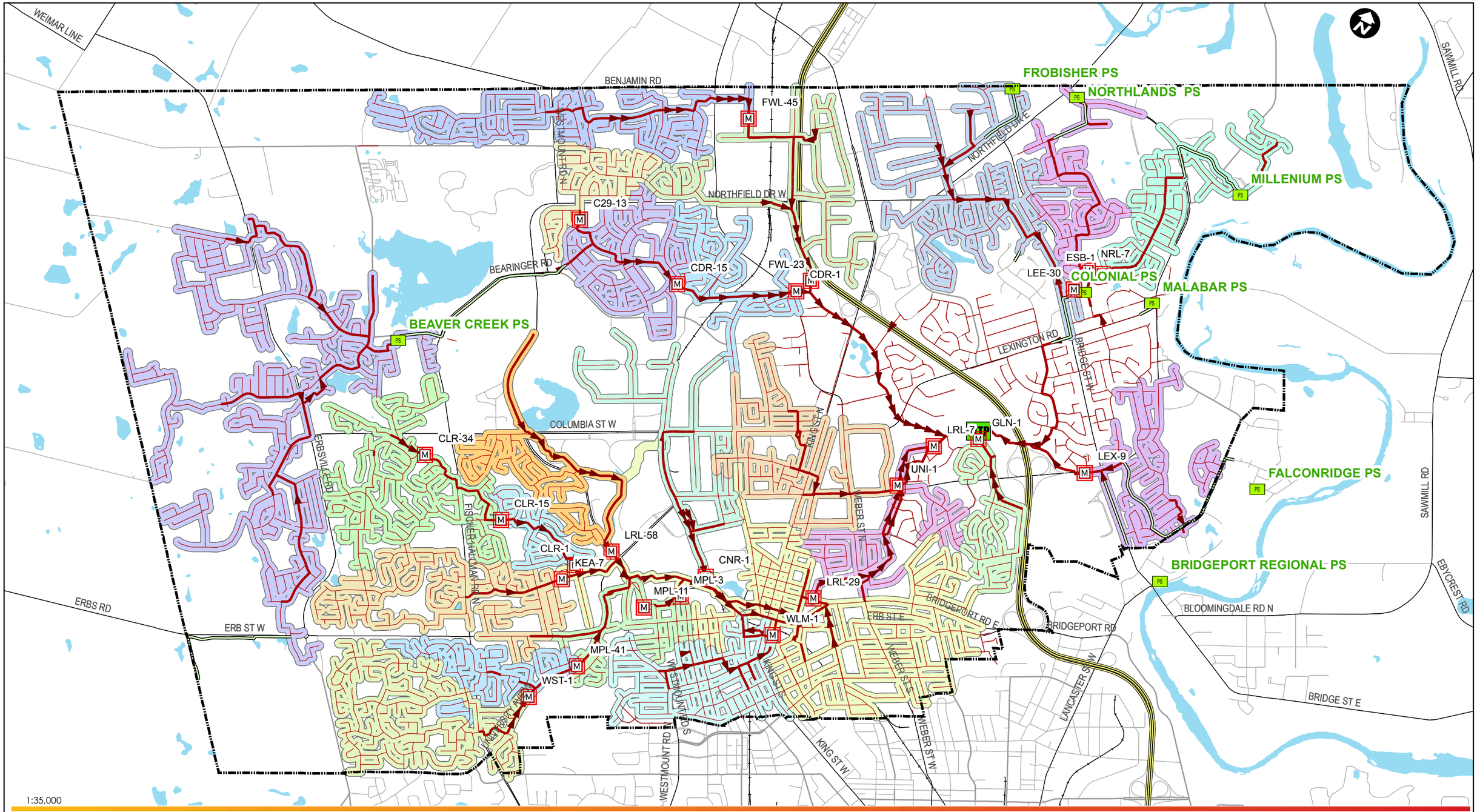
Table 6: Earth Tech - Typical Dry Weather Base Infiltration.

MH ID	Trunk	Theoretical DWF[1] (L/s/ha)	Measured Peak DWF (L/s/ha)
CDR-1 [2]	Lower Cedar	0.234	0.405
CDR-15 [2]	Cedar Trunk at Cedarbrae	0.269	0.414
CLR-1 [2]	Clair	0.188	1.782
CLR-15 [2]	Mid Clair at Craigleigh	0.191	0.372
CLR-34 [2]	Upper Clair	0.208	0.302
CNR-1	CNR	0.253	0.380
C29-13 [2]	Cedar Trunk at Highpoint	0.186	0.349
ESB-1	Eastbridge Trunk	0.400	0.000
FWL-2	Lower Forwell	0.444	0.224
FWL-23	Middle Forwell	0.135	0.105
FWL-46 [2]	Upper Forewell	0.178	0.156
GLN-1	Glenridge	0.400	0.714
KEA-7	Keats	0.168	0.374
LEE-1	Lee/Dunvegan	0.194	0.307
LEE-30	Lower Lee Dunvegan	0.136	0.164
LEX-9	Lexington	1.000	3.000
LRL-7	Lower Laurel at STP	0.248	0.335

MH ID	Trunk	Theoretical DWF[1] (L/s/ha)	Measured Peak DWF (L/s/ha)
LRL-29	Middle Laurel at Bridge	0.251	0.352
LRL-58	Upper Laurel at Westmount	0.485	0.291
MPL-3	Maple Hill	0.209	0.058
MPL-11 [2]	Maple at Father David B.	0.210	0.892
MPL-41	Maple Hill at Redwood	0.254	0.373
NRL-7	Northland Trunk on Eastbridge	0.833	0.000
UNI-1	University	0.237	0.356
WLM-1 [2]	William	0.375	0.800
WST-1	Westvale	0.189	0.170

Note 1:Theoretical flow is calculated using the design loading rates of 270 L/c/d for residential populations, 230 L/c/d for employment population, 230 L/c/d for residential students at the two universities, and 55 L/s/d for non-residential students at the two universities.

Note 2: These monitors are from the EarthTech 2002 study. All other data is assumed to originate from previous studies including the 1994 Gore & Storrie Study, and the 2012 CRA Study.



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Stantec Consulting Ltd.
49 Frederick Street
Kitchener, Ontario, Canada
N2H 6M7
Tel: (519) 579-4410
Fax: (519) 579-6733
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- M Flow Monitor Locations

Figure No. FIG-3

Title **EARTHTECH FLOW MONITOR LOCATIONS AND COVERAGE (2002)**

Client/Project City of Waterloo
Waterloo Sanitary Master Plan

Rainfall data was obtained from the Laurel Creek Conservation Area, Operated by the Grand River Conservation Authority (GRCA). Overall results of this flow monitoring program identified four priority areas: Clair Trunk, Cedar Trunk, William Trunk, Laurel, University, and Glenridge.

2.1.4 Clair Sewershed I/I Pilot Project (Stantec, 2012)

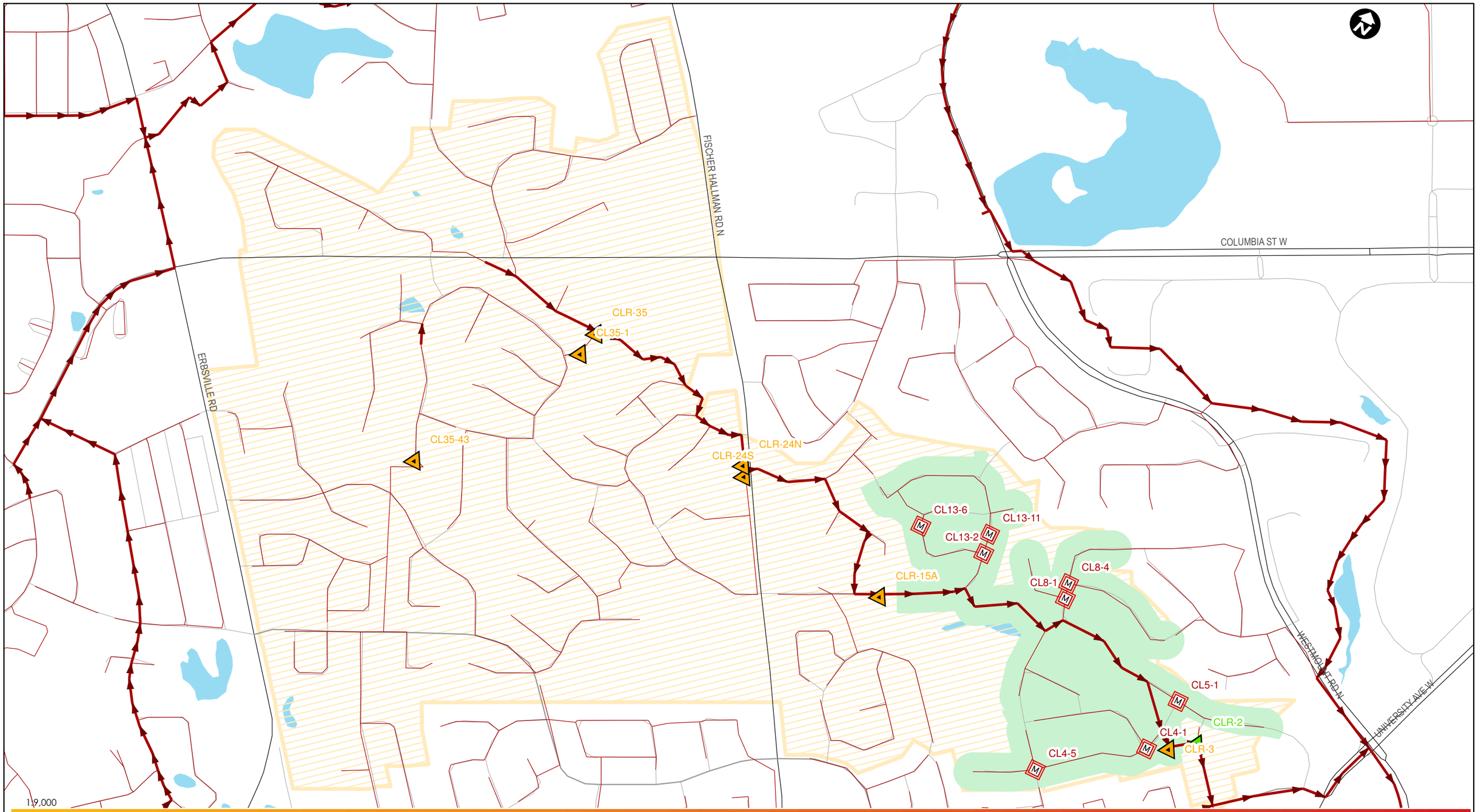
An Inflow/Infiltration (I/I) Investigation and Remediation Pilot Program was completed in the Clair Creek Sewershed in Waterloo. The observed groundwater infiltration rates were highest for flow monitors CLR-3 and CLR-15A. A second phase of the project was completed within the subcatchment area between these two monitors (refer to Figure 4). The second phase of the project included micromonitoring, CCTV inspection review, and investigation of the influence of Region of Waterloo Well W10 on observed wastewater flows (identified in background review).

A total of 25 rain events were captures and assessed in the first phase of the project. Table 7 provides a summary of the rainfall events and wet weather responses.

Table 7: Peak Wet Weather Responses for CLR-3 and CLR-15A

	Total Rain (mm)	CLR-3 (L/s/ha)	CLR-15A (L/s/ha)
Maximum	46.0	4.0	1.6
Minimum	15.2	0.0	0.1
Average	23.5	0.6	0.7

The micromonitoring program in the second phase of the project took place over 10 weeks in year 2012. There were 11 monitors installed within the Clair Sewershed, between flow monitors CLR-3 and CLR-15A (from Phase 1). The base flow has been provided for each monitor in Table 8. The monitor locations are depicted in Figure 4.



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- Local Sewers
- Trunk Sewers

- AGM Flow Monitors
- CANAM Flow Monitors
- Stantec Micromonitors

1611-11191

Figure No. FIG-4

Title **Stantec Flow Monitor Locations (2002)**

Client/Project CITY OF WATERLOO SANITARY SERVICING MASTER PLAN UPDATE

Table 8: Clair Sewershed - Base Flows

Waterloo MH ID	Description	Drainage Area (ha)	Base Flow (L/s/ha)
CL13-2a	Combermere	14.74	0.048
CL13-2b	Craigleith north of Combermere	7.03	-
CL13-6	Combermere (downstream of 30 Combermere Cr.)	11.24	-
CL4-1a	Hiawatha	6.84	0.031
CL4-5a	Coleridge	3.60	0.017
CL4-5b	Amos	1.62	0.185
CL5-1	Shakespeare and Coleridge	5.24	0.017
CL8-1	Shakespeare and Browning	3.11	0.000
CL8-4a	Shakespeare	4.91	0.010
CL8-4b	Mohawk	6.32	0.005
CL13-11	Craigleith	4.36	0.050

The monitoring program identified that dry weather infiltration is generally distributed across the drainage area, and significant wet weather responses were not observed during the monitoring period. Two areas exhibited more significant contributions including CL13-2 (Combermere) and CL13-11 (Craigleith). These findings confirming that infiltration, rather than inflow is an issue in this drainage area. This differs, however, from the 2002 City Wide Sanitary Sewer System Update Master Plan which suggested that this sewershed was subjected to significant inflow response.

The flow monitoring was followed by a CCTV inspection of suspect sewers and laterals to verify sources of observed infiltration. Some deficiencies were identified with the laterals, including some which were attributed to the original construction of the sewers.

The operation of Region of Waterloo Well W10 lowers the groundwater table in the Clair subsewershed to a point where groundwater infiltration flows are reduced by approximately 4 L/s. The monitors measuring affected flows include CL13-2 (Combermere) and CL13-11 (Craigleith). It is not anticipated that Well 10 will be run continuously in the future; therefore, an additional groundwater infiltration flow was estimated and added to the previously determined base flow through flow monitoring.

It should be noted that 2012 was an unusually dry year and therefore the flows observed may not have been representative of typical flows.

2.2 INTERPRETATION OF RESULTS

Based on the review of historical flow monitoring, the areas with the highest reported I/I rates include the University Trunk, Cedar Trunk, and William Trunk, Clair Trunk, and the Beechwood/ Erbsville Trunk:

- **The University Trunk** (W2, UNI-1) exhibited high base infiltration rates of 0.208 L/s/ha during the spring, but more acceptable rates of 0.089 L/s/ha. This area produced a wet weather response of up to 0.313 L/s/ha (Gore and Storrie, 1994).

- **The Cedar Trunk** (W8, CDR-1) exhibited a peak base infiltration value of 0.324 L/s/ha, and during the rest of the year they dropped to 0.109 L/s/ha. The total wet weather I/I peaked at 0.423 L/s/ha but was more typically averaging 0.246 L/s/ha (Gore and Storrie, 1994).

- **The William Trunk** (W10, WLM-1) exhibited base infiltration rates reaching 0.197 L/s/ha in the spring, and 0.137 L/s/ha in the summer. Total wet weather was measured as high as 0.491 L/s/ha during the spring, and 0.208 L/s/ha (Gore and Storrie, 1994).

- **The Clair Sewershed** (W15, CLR-1) exhibited base infiltration rates ranging from 0.300 to 0.450 L/s/ha. The Clair Trunk (W15) exhibited a spring base infiltration of 0.521 L/s/ha and more typically 0.347 L/s/ha. The wet weather I/I was measured to be 0.468 L/s/ha (Gore and Storrie, 1994).

  Contrarily, the Clair Sewershed I/I Pilot Project (Stantec, 2012) reported base flows within the Clair sewershed ranging up to 0.050 L/s/ha with the exception of monitor CL4-5b which has a base flow of 0.185 L/s/ha, this catchment includes flows from Centennial Public School which services 500 students. The Clair Sewershed I/I Pilot Project concluded that wet weather responses were not significant during the monitoring program. It should be noted that the Gore and Storrie monitor location is associated with a much larger sewershed than that of the Clair Sewershed I/I Pilot Project which had many monitors in a more localized area.

- **Beechwood/Erbsville Area** contained four monitors within the CRA study (1998). These four monitors were located within a very localized area, and the average dry weather flows ranged up to 0.081 L/s/ha, with the exception of monitor K53-7 Sandbury Lane which had dry weather flows of 0.205 L/s/ha. The Sandbury Lane area collects leachate at the time from the Erb Street Landfill.

  Wet weather responses for this area ranged from 0.001 to 0.013 L/s/ha with the exception of Sandbury Lane which observed wet weather flows of 0.496 L/s/ha. Sandbury Lane receives leachate flows from the Erb Street Landfill, therefore the true wet weather contribution (excluding landfill leachate flows) were 0.149 L/s/ha. The I/I

observed in this area was mostly attributed to wet weather inflow rather than groundwater infiltration.

The Gore and Storrie Report (1994) reported base flows for the Keats sewershed (W16, KEA-8) which is downstream of the Beechwood/Erbsville CRA monitoring location. This flow monitor observed flows ranging up to 0.104 L/s/ha. It should be noted that the Gore and Storrie monitor location is associated with a much larger sewershed than that of the CRA Study (1999). The total wet weather flow observed for monitor W16 was reported as less than the design value of 0.15 L/s/ha, therefore this area was not identified as problematic.

It should be noted that four of these five areas were identified in the Gore and Storrie Report (1994), which is also the oldest of all available reports. There have been many changes to the sanitary network since 1994, including new developments, twinned sewers, and other adjustments to the network.

3.0 2013 FLOW MONITORING COVERAGE

This section summarizes the 2013 flow monitoring campaign in terms of overall coverage and data quality. The intention is to gain an understanding of the usable data for both model calibration and infiltration/inflow assessment, and to identify gaps in coverage. This information has been used to develop the needs for future flow monitor deployment in 2014. The additional flow monitoring on 2014 has been used to validate model assumptions and calibration efforts.

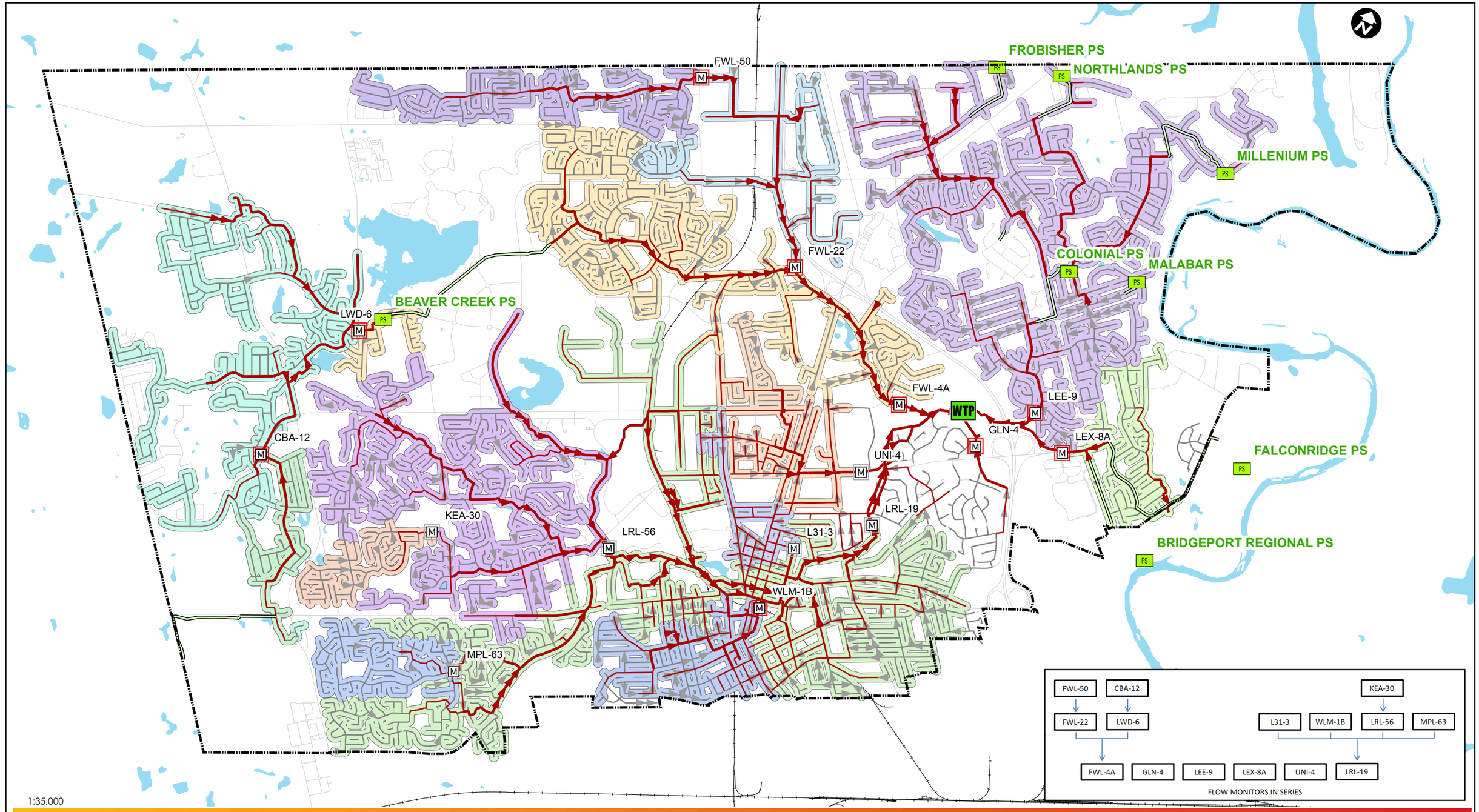
3.1 OVERVIEW OF FLOW MONITORING PROGRAM

The 2013 flow monitoring campaign was conducted for the purposes of characterizing flow for use in the master planning process. There are a total of 15 monitoring locations situated across the City, as depicted in Figure 5. The pipe diameter and the dates of data collection for each monitoring location are summarized in Table 9.

Table 9: Summary of Existing Flow Monitoring Locations

Flow Monitor		Pipe Size	Data Time Period	
AMG ID	SFM ID	(mm)	Start Date	End Date
CBA-12	FM-001	375	14-May-13	8-Jan-14
FWL-4A	FM-002	825	15-May-13	8-Jan-14
GLN-4	FM-003	425	15-May-13	8-Jan-14
LEE-9	FM-004	600	15-May-13	8-Jan-14
LEX-8A	FM-005	825	15-May-13	8-Jan-14
LRL-56	FM-006	750	14-May-13	16-Sep-13
LWD-6	FM-007	750	14-May-13	8-Jan-14
KEA-30	FM-008	250	12-Dec-12	30-Jun-13
MPL-63	FM-009	300	11-Dec-12	17-Jul-13
L31-3	FM-010	250	11-Dec-12	19-Jun-13
UNI-4	FM-011	600	12-Dec-12	22-Jul-13
LRL-19	FM-012	1200	12-Dec-12	24-Jun-13
WLM-1B	FM-013	525	25-Jun-13	8-Jan-14
FWL-22	FM-014	600	23-Oct-13	8-Jan-14
FWL-50	FM-015	375	23-Oct-13	8-Jan-14

Some monitors are connected in series, which means that a downstream catchment area will receive flow from an upstream catchment area, as depicted in Figure 5. It is important to recognize monitors in series because the downstream catchment area will be affected by the flow characteristics of the upstream catchment areas. The monitors are sequenced in this order for discussion within this section of the report.



1:35,000

Stantec
Stantec Consulting Ltd.
49 Frederick Street
Kitchener, Ontario, Canada
N2H 6M7
Tel: (519) 579-4410
Fax: (519) 579-6733
www.stantec.com

Legend

- CityBoundary
- Water Body
- PS Existing Pump Station
- Forcemain
- WTP Wastewater Treatment Plant

All Sanitary Sewers
- Local Sewers
- Trunk Sewers

Model Selection Set
- Local Sewers
- Trunk Sewers

Current Flow Monitors
- M Existing Monitors
- M Existing Monitors (Removed)

1611-11191

Figure No. FIG-5

Title **2013 FLOW MONITOR LOCATIONS AND COVERAGE**

Client/Project CITY OF WATERLOO SANITARY SERVICING MASTER PLAN UPDATE

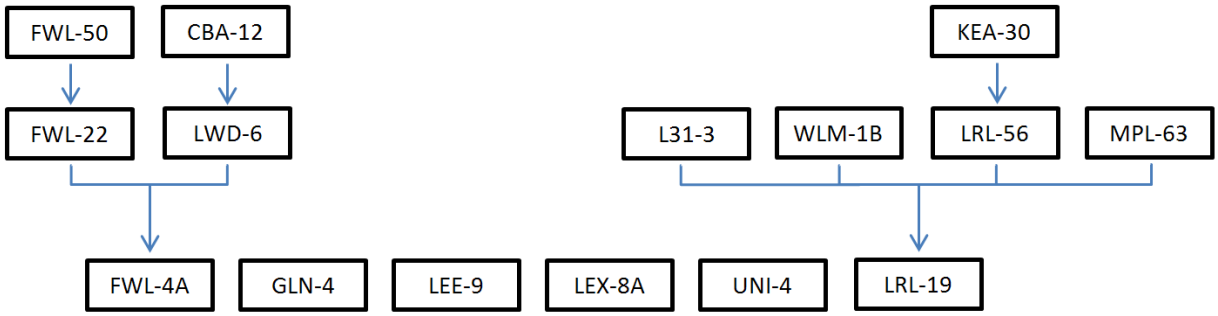


Figure 6: Connectivity of Flow Monitors in Series

The temporal coverage of flow monitoring data is presented in the table below. When calibrating the model, it is beneficial to select data from similar time periods for each monitor. Based on Figure 7 there are many months in which multiple flow monitors have collected data.

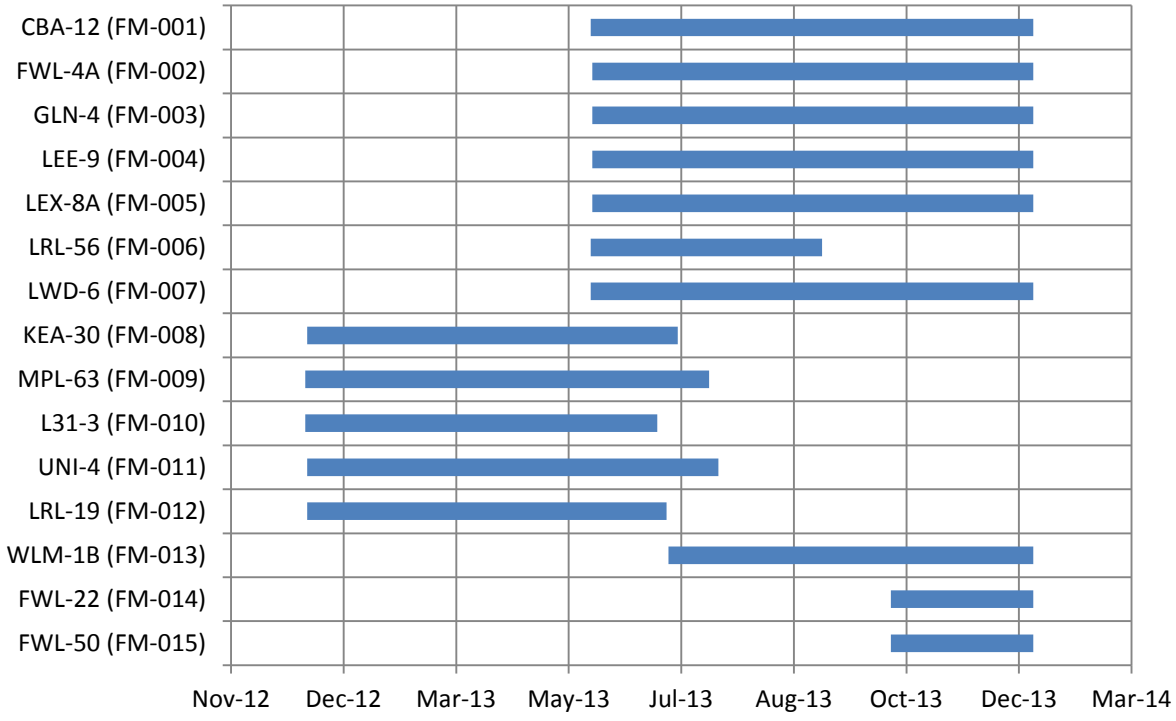


Figure 7: Monitoring Durations for Each Location

The rainfall data used for the analysis is provided by AMG. The AMG rain gauge is located at the Waterloo Landfill site. The rainfall data was compared to rainfall from the University of Waterloo Weather Station (UW Weather Station), the Environment Canada Weather Station located at the Kitchener Waterloo Airport (EC – Airport), and the City of Kitchener rain gauge located at City Hall (CofK Gauge – City Hall) for quality control. The cumulative rainfall for each of the rainfall gauges is displayed in Figure 8.

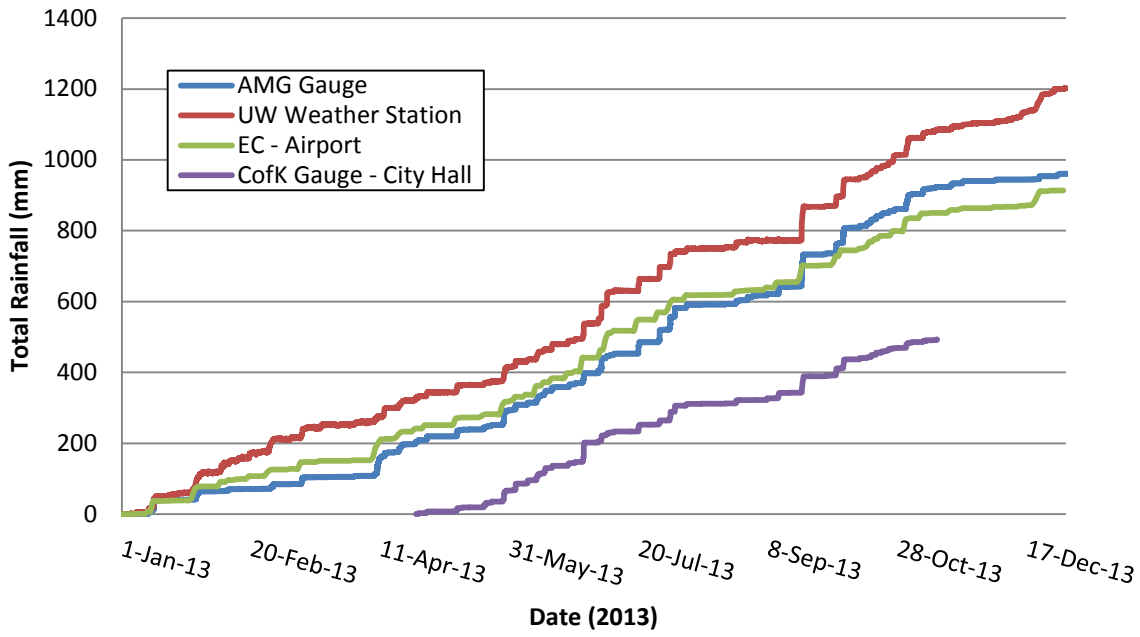


Figure 8: Comparison of Cumulative Rainfall Data for Local Rain Gauges

During winter months, snow melt events can evoke a similar system response within the sanitary network to that of a rainfall event. Periods within the data which portray elevated levels of extraneous flow but do not correlate to a rainfall event were excluded from use in model development. These periods are identified by reviewing the data against temperature data to verify the likelihood of a snow melt event.

3.2 OVERVIEW OF FLOW MONITOR RAW DATA

The raw flow data was reviewed in January of 2014 in advance of model development. The data was reviewed for quality and to identify missing data. For each flow monitoring location the level, velocity, and flow data was plotted over time along with the precipitation from the AMG gauge, as well as a scatterplot of the velocity and level data independent of time (refer to Figure 9 through Figure 26). General comments on dry weather patterns, base flow, flow response to rain, and overall data quality are discussed.

3.2.1 Flow Monitor FWL-50 (FM-015)

Flow Monitor FWL-50 (FM-015) is located near the intersection of Weber Street and Benjamin Road. Data has been collected since October 23, 2013 and remained active into January 2014, and is shown in Figure 9. This monitor is installed in the 375 mm Forewell Trunk sewer.

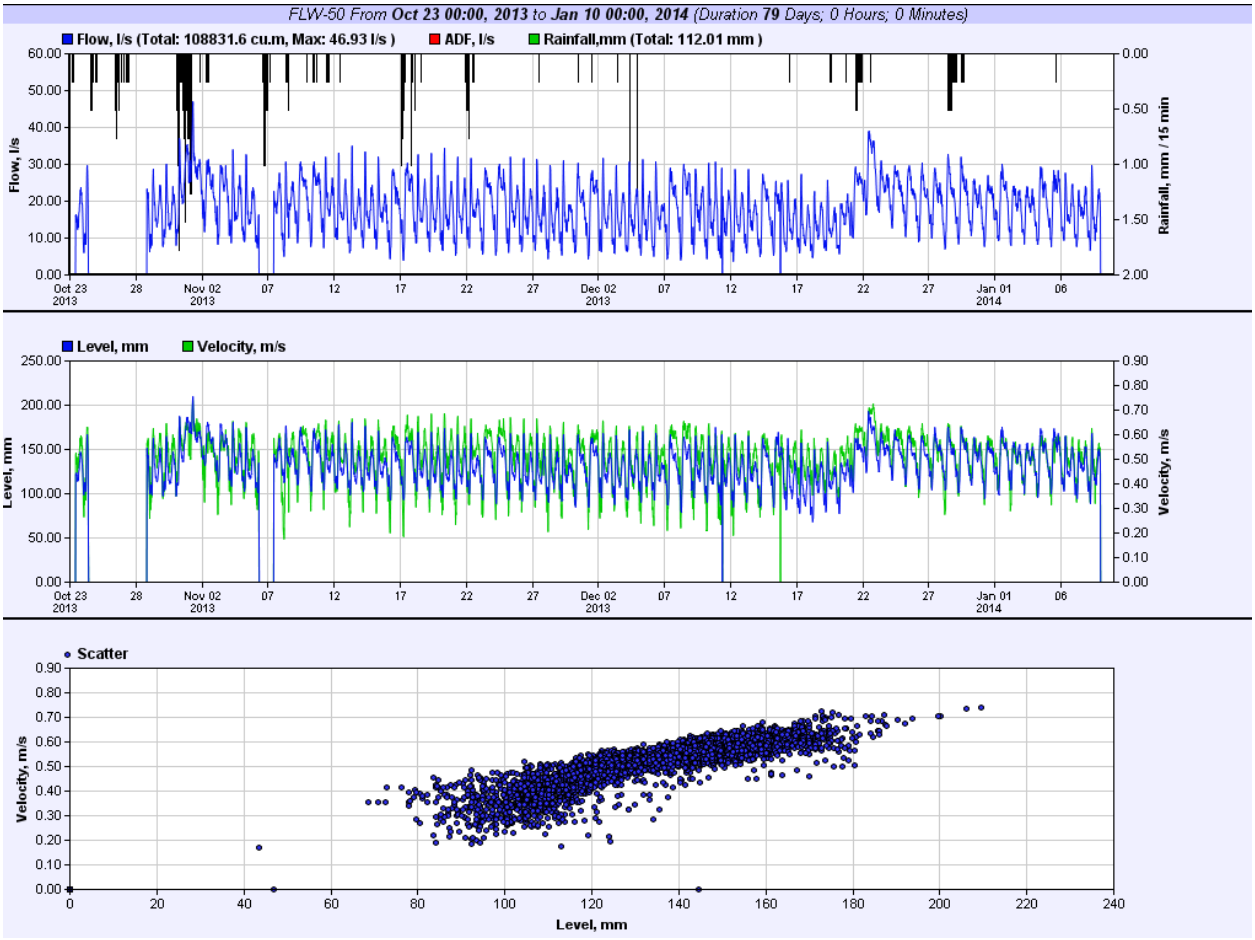

FLW-50 From Oct 23 00:00, 2013 to Jan 10 00:00, 2014 (Duration 79 Days; 0 Hours; 0 Minutes)
Flow, l/s (Total: 108831.6 cu.m, Max: 46.93 l/s)
ADF, l/s
Rainfall,mm (Total: 112.01 mm)
Flow, l/s
Rainfall, mm / 15 min
Level, mm
Velocity, m/s
Scatter
Velocity, m/s
Level, mm

Figure 9: Raw Data Review - FWL-22 (Upper Forewell Trunk)

The data has few peaks and shows a consistent flow pattern, indicating that that the wet weather flow response may be insignificant. There are some brief periods of missing data in late October and early November. The scatter plot displays a strong correlation between velocity and level with few significant outliers. This indicates good data quality, which can be used to establish model calibration parameters and infiltration and inflow characteristics.

3.2.2 Flow Monitor FWL-22 (FM-014)

Flow Monitor FWL-22 (FM-014) is located near the intersection of Weber Street and Albert Street. Data has been collected since October 23, 2013 and remained active at the time of data review (January 2014); the data is shown in Figure 10. This monitor is installed in the 600 mm Forewell Trunk sewer.

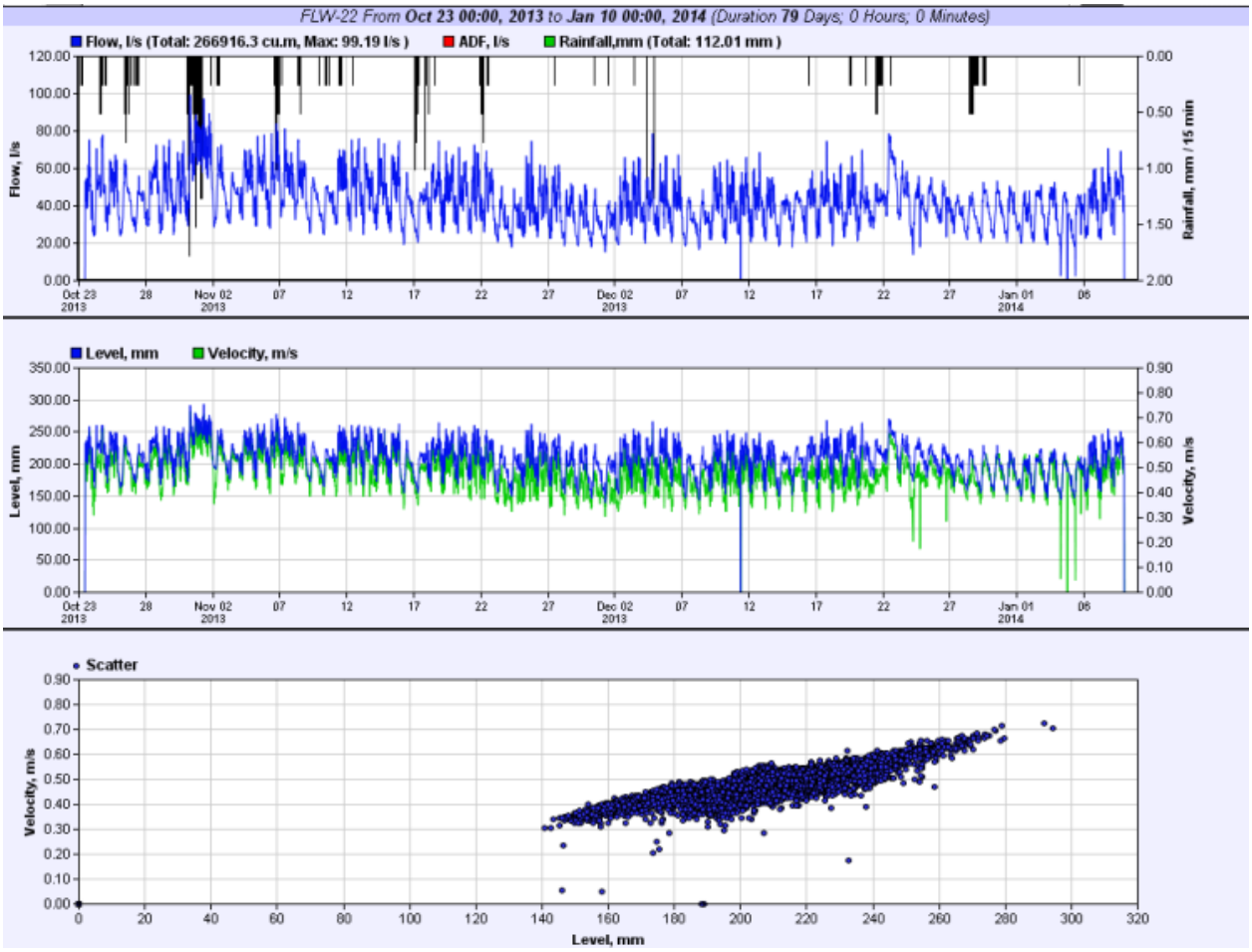

FLW-22 From Oct 23 00:00, 2013 to Jan 10 00:00, 2014 (Duration 79 Days; 0 Hours; 0 Minutes)
Flow, l/s (Total: 266916.3 cu.m, Max: 99.19 l/s)
ADF, l/s
Rainfall,mm (Total: 112.01 mm)
Flow, l/s
Rainfall, mm / 15 min
Level, mm
Velocity, m/s
Scatter
Velocity, m/s
Level, mm

Figure 10: Raw Data Review - FWL-22 (Middle Forewell Trunk)

The data has few peaks and shows a consistent flow pattern, indicating that the wet weather flow response may be insignificant. There are some missing data points and low velocity readings. These points are suspect and recommended to be removed or corrected prior to further analysis. The scatter plot displays a strong correlation between velocity and level with few significant outliers. This indicates good data quality, which can be used to establish model calibration parameters and infiltration and inflow characteristics.

3.2.3 Flow Monitor CBA-12 (FM-001)

Flow Monitor CBA-12 (FM-001) is located along Columbia Street West, west of Erbsville Road. Data has been collected since May 14, 2013 and is currently still active into January 2014; the data is shown in Figure 11. This monitor is installed the 375 mm Clair Hills Trunk sewer.

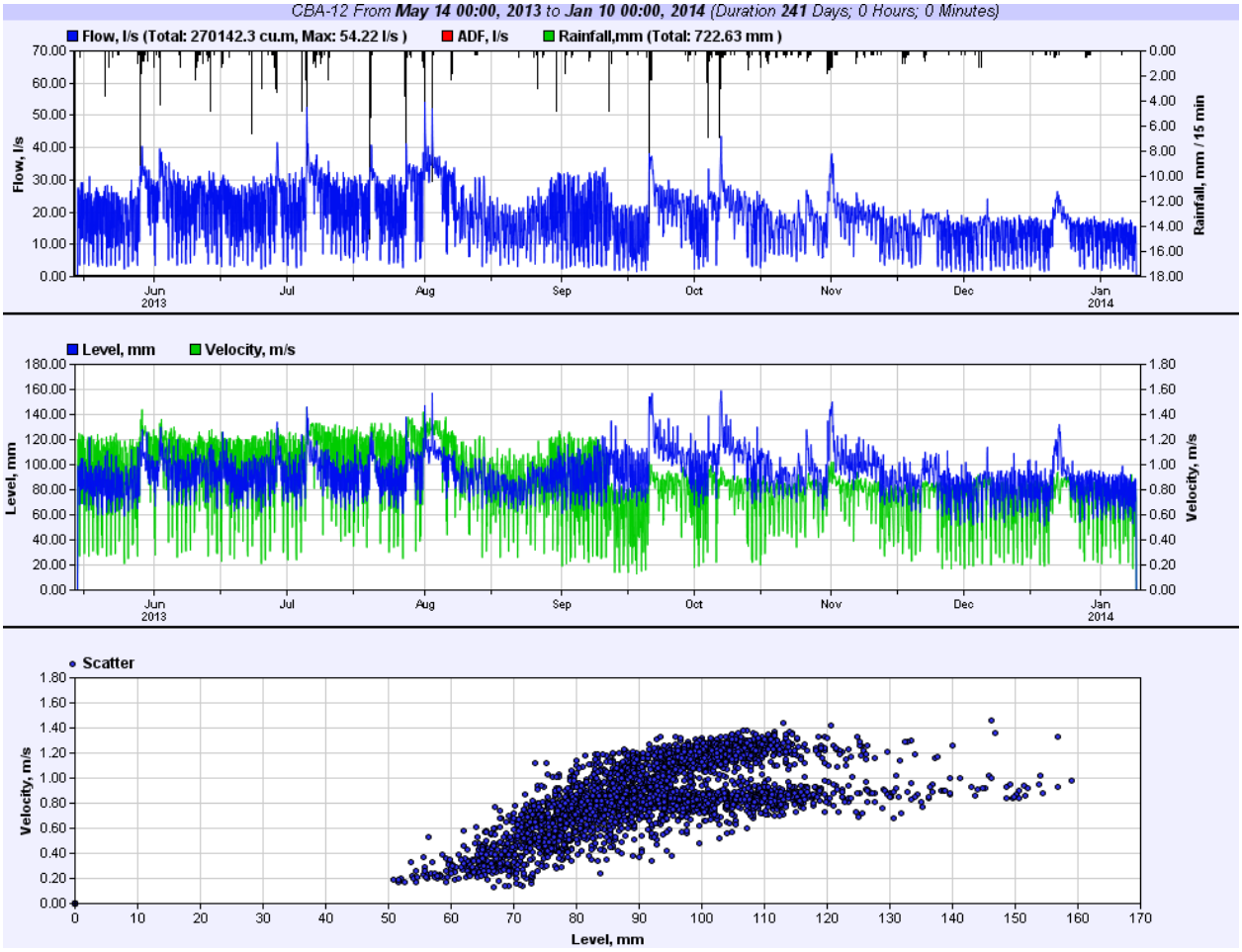


Figure 11: Raw Data Review - CBA-12 (Clair Hills Trunk)

The depth and velocity readings correlate well, as shown in the scatter plot. The scatter plot shows a divergence in the correlation, which is apparent with level readings of greater than 90 mm. This divergence is curious, and warrants further investigation. There is a moderate response to wet weather flows, which implies that inflow and infiltration may be significant within the upstream catchment. The data quality is acceptable and model calibration parameters and infiltration/inflow characteristics can be established.

The CBA-12 subcatchment receives leachate flows from the Erb Street Landfill. The landfill leachate flow is plotted in Figure 12 below, along with the flow data for Flow Monitor CBA-12 (FM-001). Leachate flows are recorded at Pump Station 3 (PS3), which is located at the landfill site and pumps the leachate from the landfill site into the sanitary network. The leachate enters the network at the top of the CBA-12 subcatchment at the intersection of Erb Street and Ira Needles Boulevard. The distance between the receiving location and the downstream flow monitor results in attenuation of flows from the PS3 prior to reaching the monitor. Therefore, it is anticipated that the leachate flows do not significantly contribute to peak flows. The leachate

data (Figure 12) is reported as daily volumes; therefore, peak flows cannot be determined at a finer resolution (e.g. 5 minute).

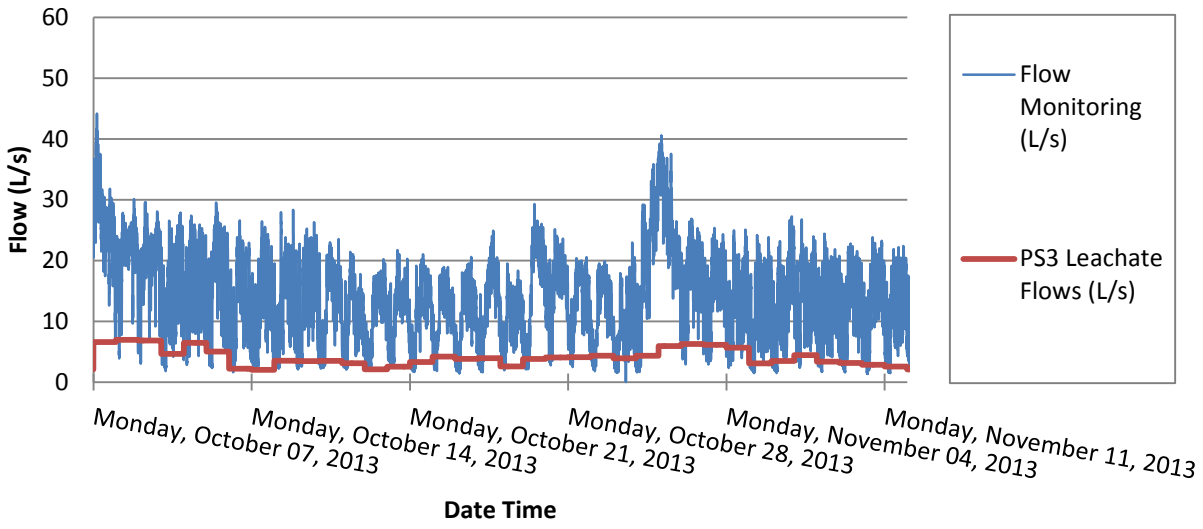


Figure 12: Comparison of Flows for Flow Monitor CBA-12 (FM-001) and the Erb Street Landfill Leachate Pump

3.2.4 Flow Monitor LWD-6 (FM-007)

Flow Monitor LWD-6 (FM-007) is located at 200 Pineland Court. Data has been collected since May 14, 2013 and remained active into January 2014, the data is shown in Figure 13 below. This monitor is installed at the 750 mm Laurelwoods Trunk sewer.

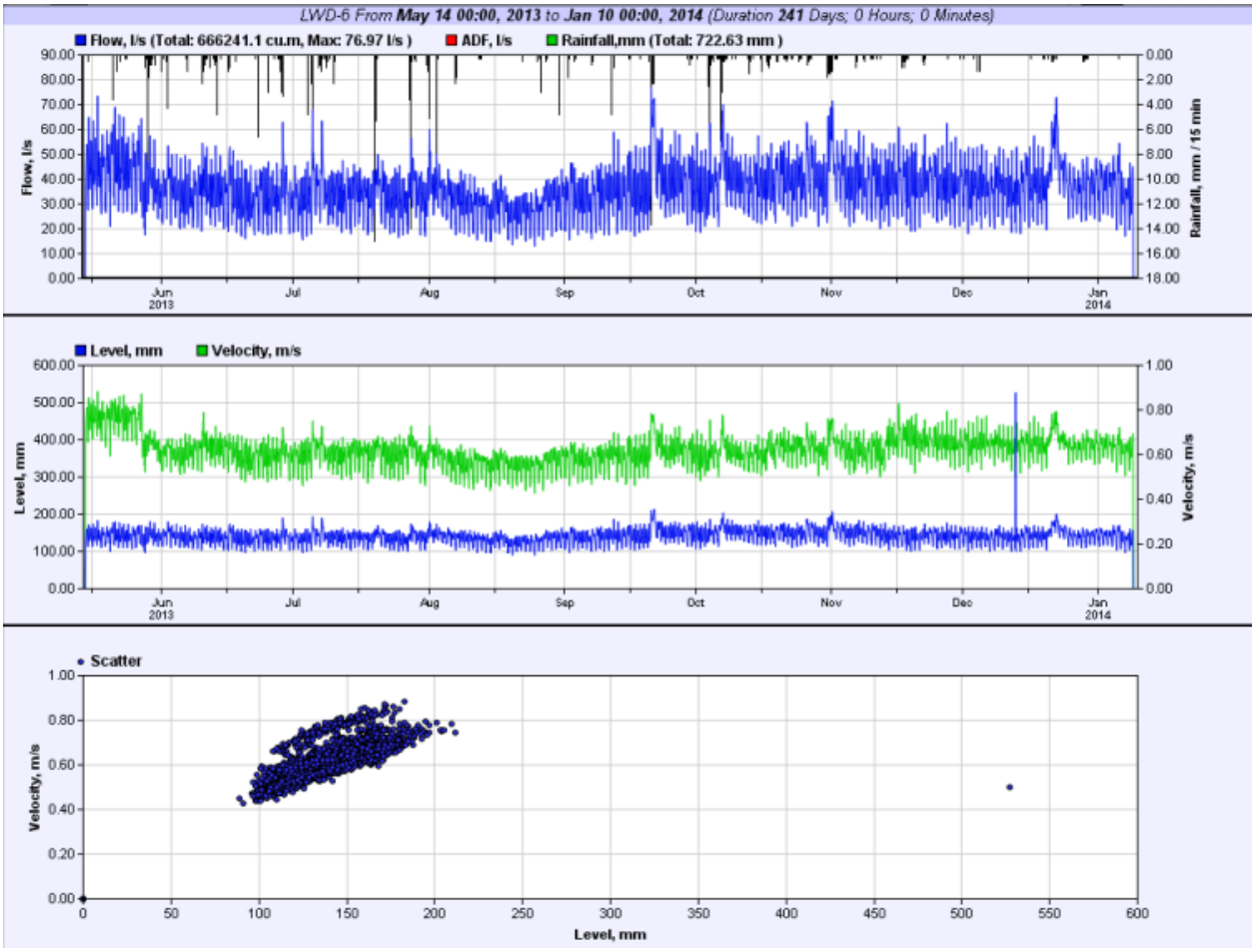

LWD-6 From May 14 00:00, 2013 to Jan 10 00:00, 2014 (Duration 241 Days; 0 Hours; 0 Minutes)
Flow, l/s (Total: 666241.1 cu.m, Max: 76.97 l/s)
ADF, l/s
Rainfall,mm (Total: 722.63 mm)
Flow, l/s
Rainfall, mm / 15 min
Level, mm
Velocity, m/s
Scatter
Velocity, m/s
Level, mm

Figure 13: Raw Data Review - LWD-6 (Laurelwoods Trunk)

The scatterplot indicates a strong correlation between the velocity and depth. There is a slight shift in average velocity values in late April 2013, which may be due to an adjustment in the equipment or a recalibration. The most significant outlier occurs on December 13, 2013 with a depth of over 500 mm, approximately 70% if the pipe diameter. The data shows a noticeable response to wet weather.

A subsection of the data is displayed in Figure 14 below, which excludes the data from April prior to the shift in velocity values, and excludes the peak level value which occurred in December 2013. This subsection of data shows a very strong correlation between velocity and level, which indicates good overall data quality. This data can therefore be used to generate model calibration parameters and I/I characteristics.

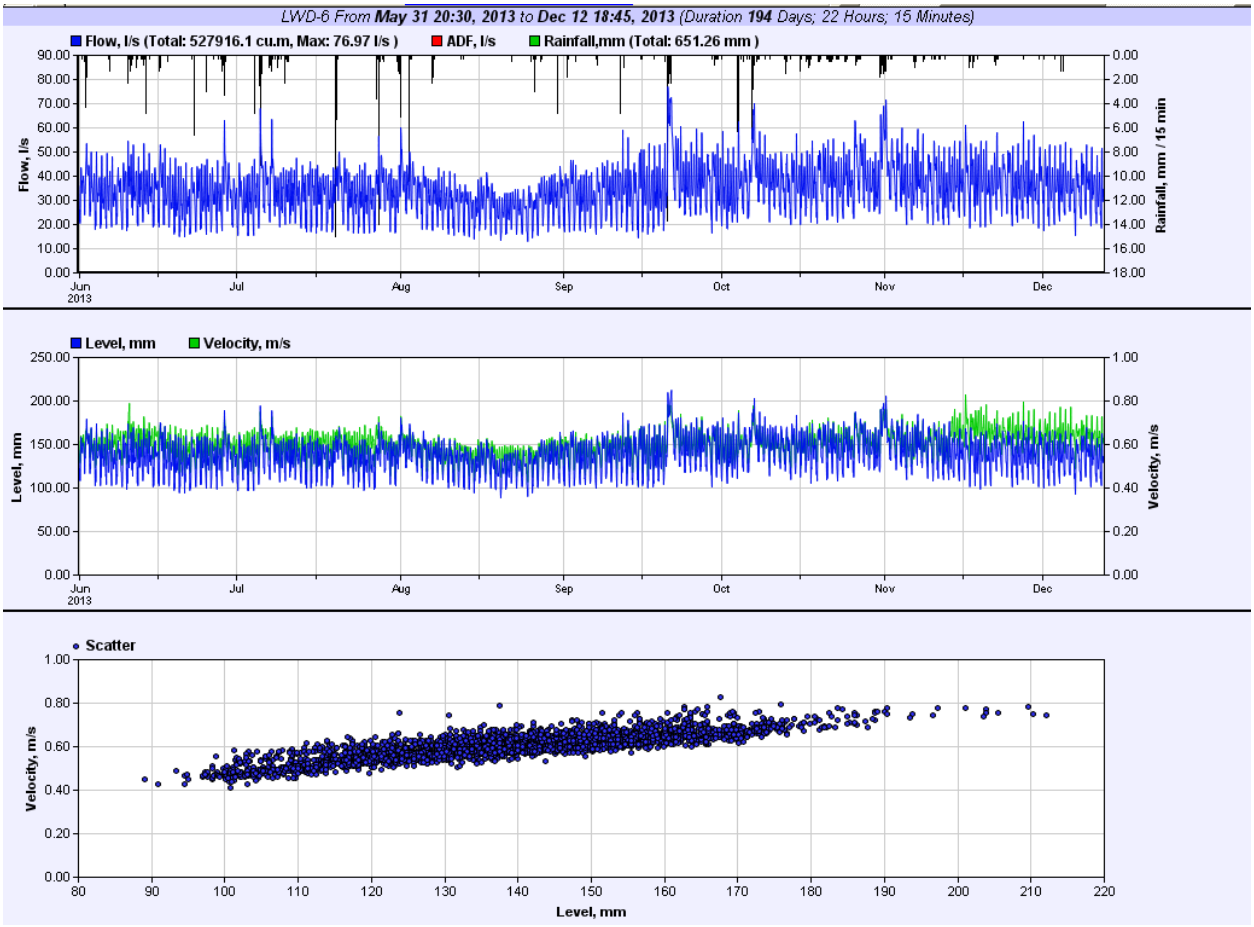


Figure 14: Raw Data Review – Subsection of LWD-6 (Laurelwoods Trunk)

3.2.5 Flow Monitor FWL-4A (FM-002)

Flow Monitor FWL-4A (FM-002) is located on the walking path west of the wastewater treatment plant. Data has been collected since May 15, 2013 and remained active into January 2014; the data is shown in Figure 15 below. This monitor is installed at the 825 mm Forewell Trunk sewer.

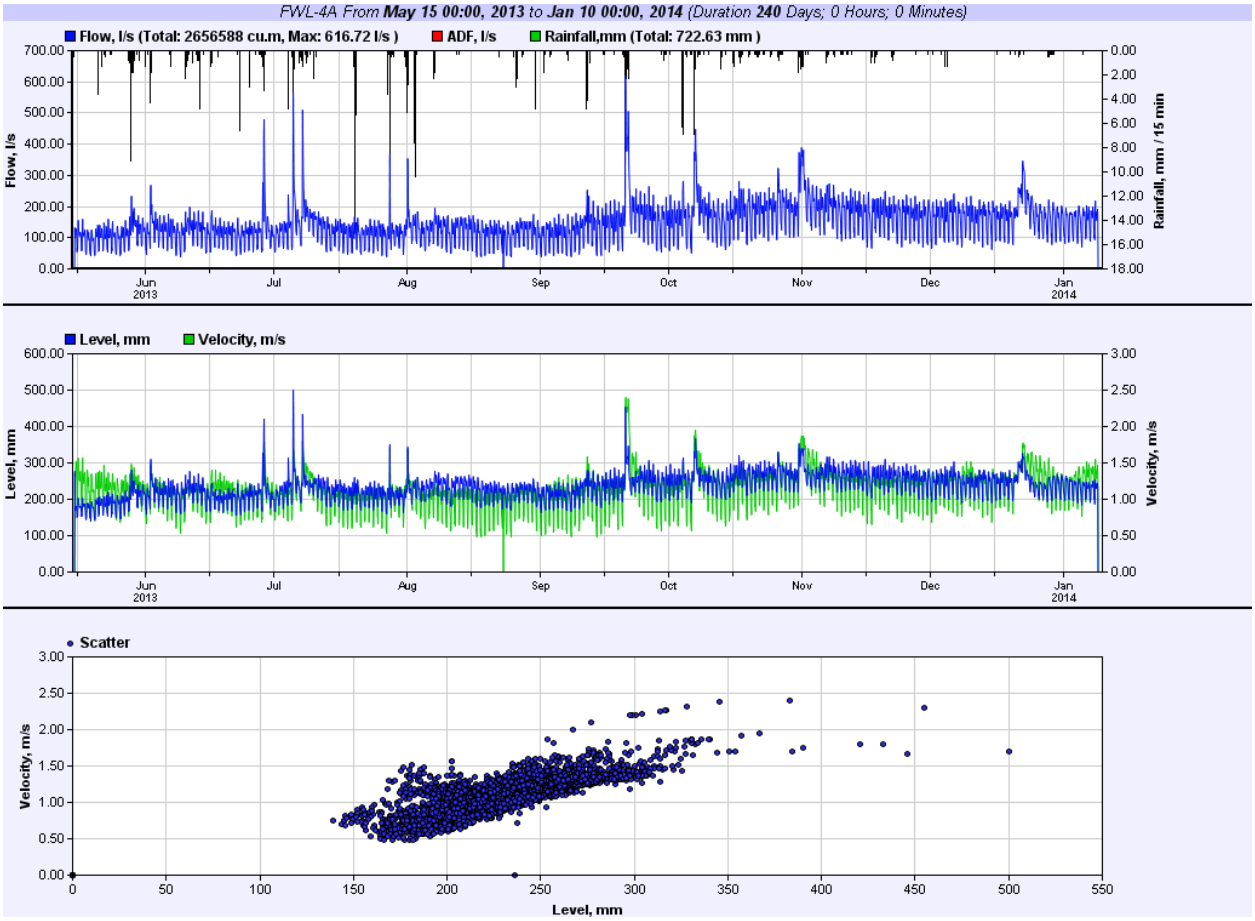


Figure 15: Raw Data Review - FWL-4A (Lower Forewell Trunk)

The scatterplot indicates a relatively strong correlation of depth and velocity, with a few anomalies throughout the time period. These level and velocity outliers should be investigated to verify data quality. The highest peak levels and flows are seen in both July and September with 500 mm being the largest recorded depth. Wet weather responses are apparent in the data after significant rainfalls. Overall, this site has good data quality that can be used to create model calibration parameters and I/I characteristics.

3.2.6 Flow Monitor GLN-4 (FM-003)

Flow Monitor GLN-4 (FM-003) is located near along the walking path east of the Wastewater Treatment Plant. Data has been collected since May 15, 2013 and remained active into January 2014; the data is shown in Figure 16 below. This monitor is installed at the 425 mm Glenridge Trunk sewer.

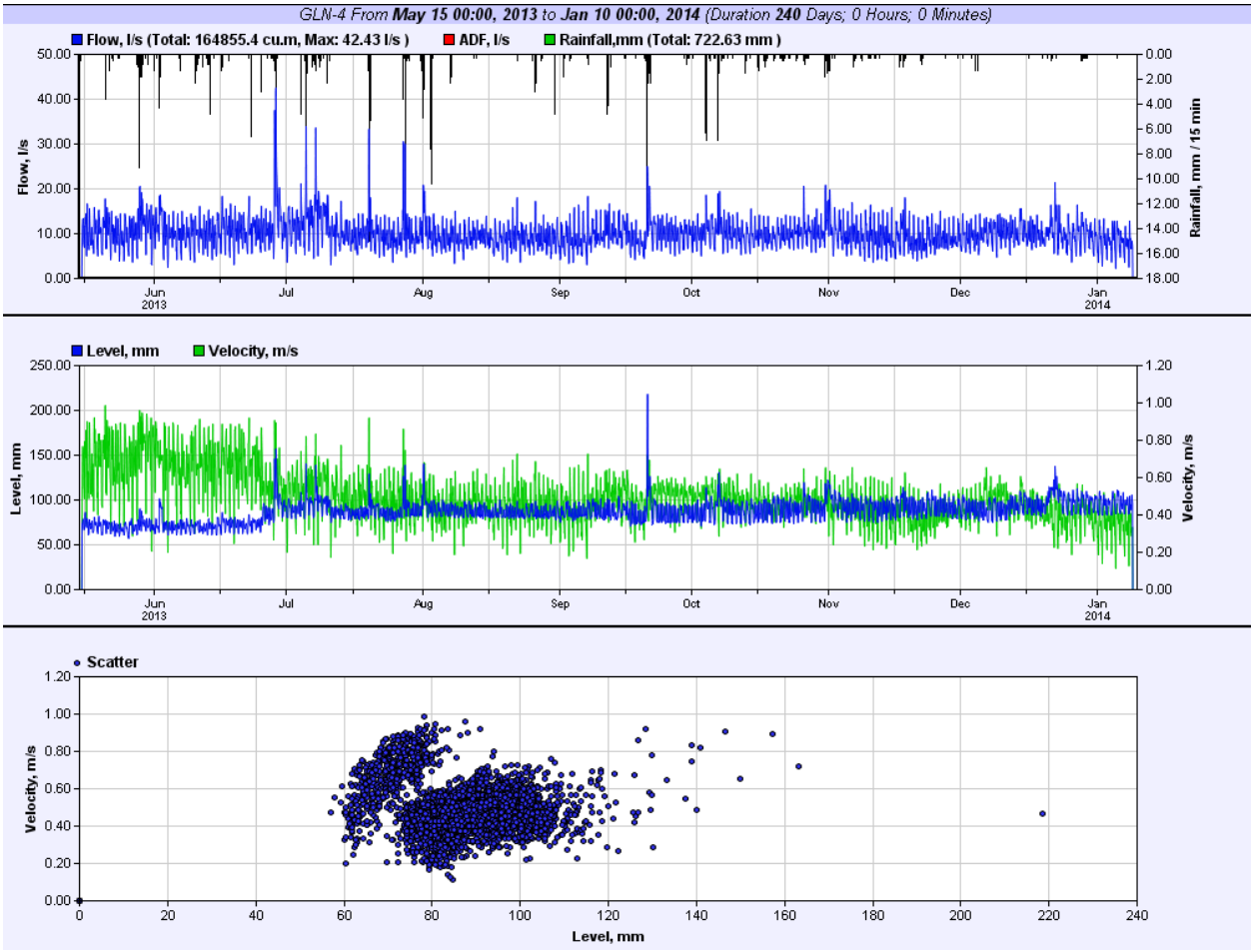

GLN-4 From May 15 00:00, 2013 to Jan 10 00:00, 2014 (Duration 240 Days; 0 Hours; 0 Minutes)
Flow, l/s (Total: 164855.4 cu.m, Max: 42.43 l/s)
ADF, l/s
Rainfall,mm (Total: 722.63 mm)
Flow, l/s
Rainfall, mm / 15 min
Level, mm
Velocity, m/s
Scatter
Velocity, m/s
Level, mm

Figure 16: Raw Data Review - GLN-4 (Glenridge Trunk)

There are a few outliers throughout the monitoring period, with the greatest irregularities occurring on September 20, 2013 with a maximum depth of 225 mm. The velocity and level plots displays consistent readings with the exception of the duration between May 15, 2013 and June 30, 2013. This shift in data values in late June has affected both the level and velocity values, and may indicate an adjustment to the equipment or a recalibration. The depth and velocity correlation shows a poor correlation, and also shows two (2) distinct correlation clusters. The two (2) distinct clusters can be attributed to the shift in values which occurred in late June. A subsection of the data is depicted in Figure 17 below which excludes the data prior to the shift in values which occurred in late June.

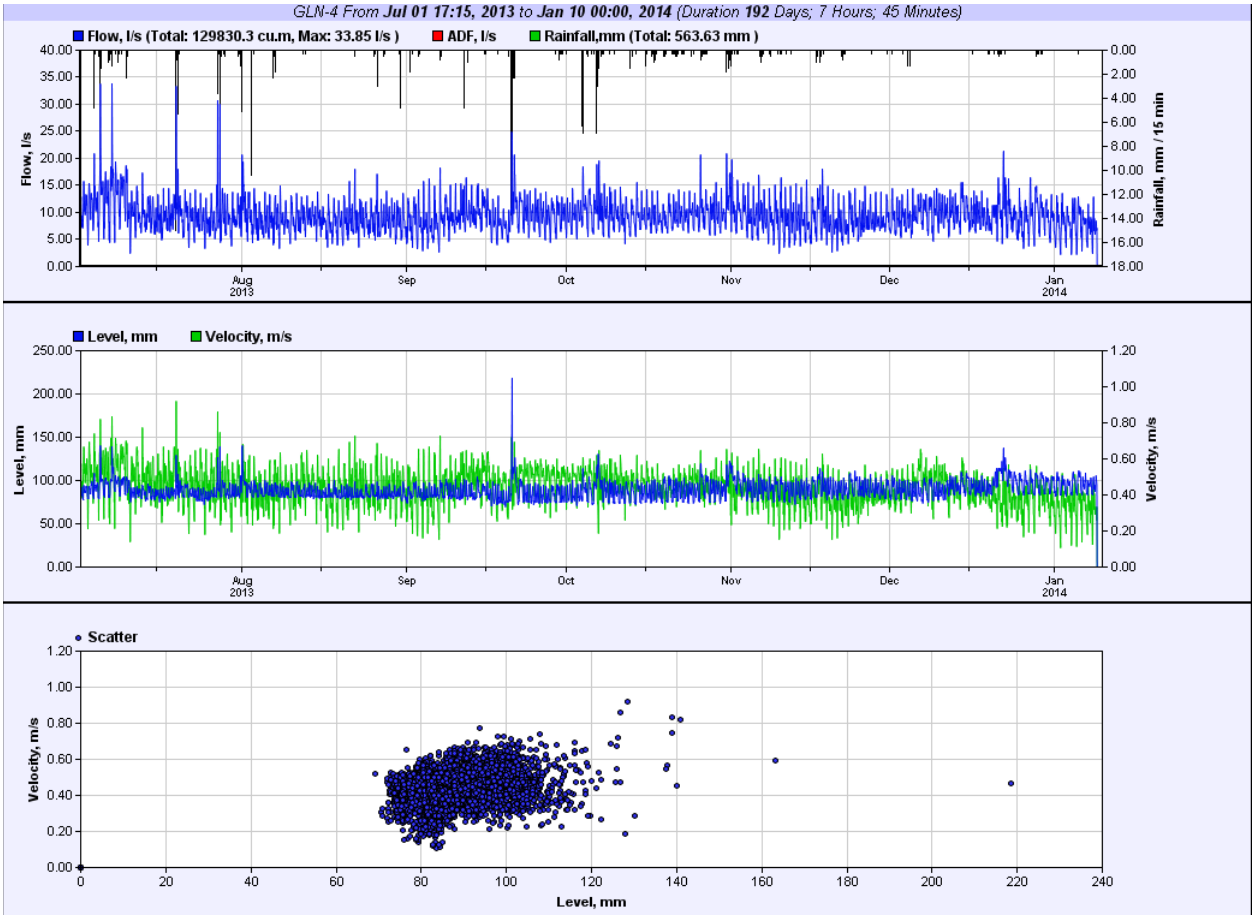


Figure 17: Raw Data Review – Subsection of GLN-4 (Glenridge Trunk)

The subsection of data displayed above, which excludes data from May and June, exhibits moderate data quality that can be used to build model calibration parameters and I/I characteristics, however, the correlation between velocity and level is still relatively poor.

3.2.7 Flow Monitor LEE-9 (FM-004)

Flow Monitor LEE-9 (FM-004) is located in grass, across from park on Sandown Drive. Data has been collected since May 15, 2013 and remained active into January 2014; the data is shown in Figure 18 below. This monitor is installed at the 600 mm Lee Trunk sewer.

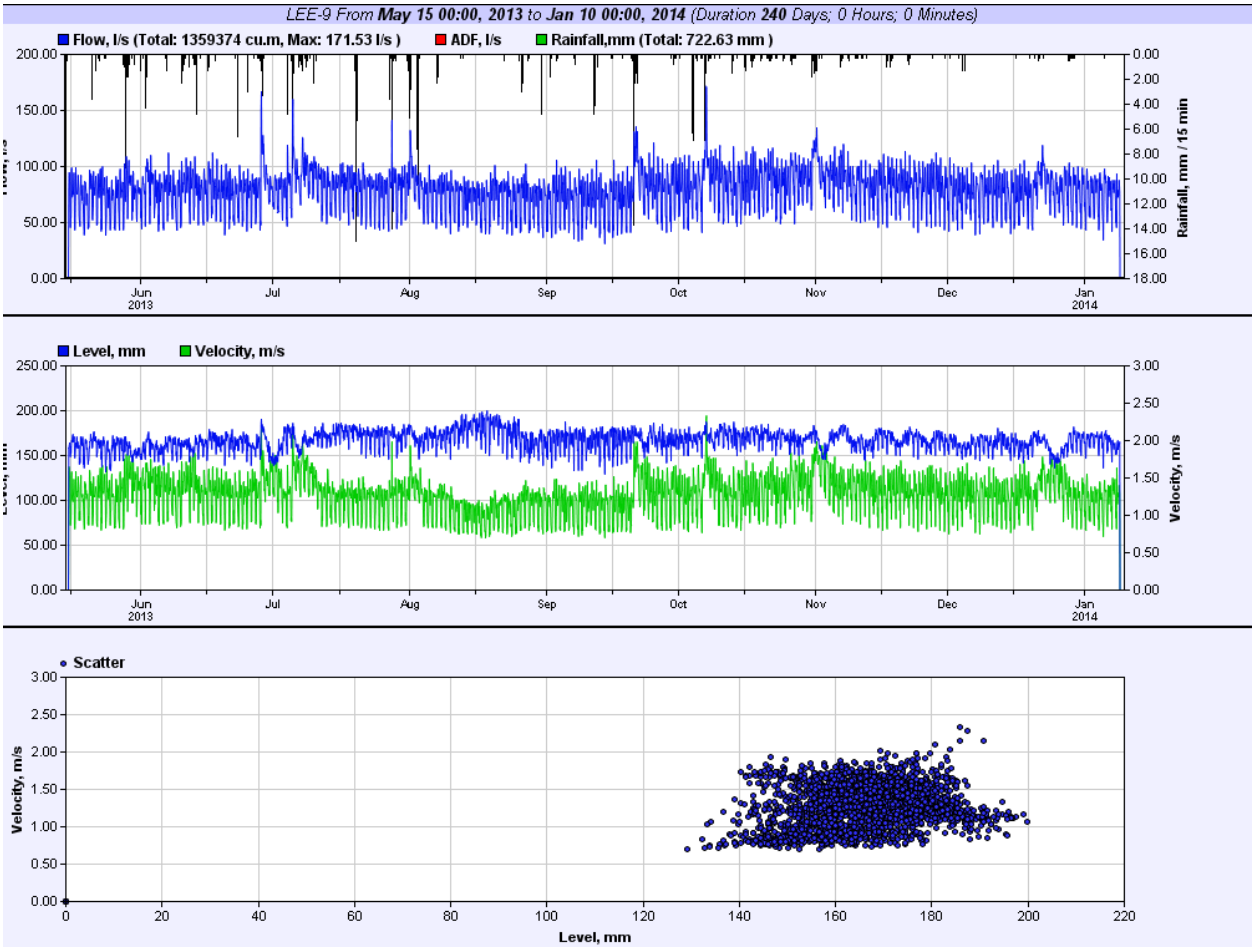

LEE-9 From May 15 00:00, 2013 to Jan 10 00:00, 2014 (Duration 240 Days; 0 Hours; 0 Minutes)
Flow, l/s (Total: 1359374 cu.m, Max: 171.53 l/s)
ADF, l/s
Rainfall,mm (Total: 722.63 mm)
Rainfall, mm / 15 min
Level, mm
Velocity, m/s
Scatter
Velocity, m/s
Level, mm

Figure 18: Raw Data Review – LEE-9 (Lee Trunk)

The scatterplot presents consistent ranges of both the depth and velocity over this monitoring period, however a relatively poor correlation. Peaks in flow are observed which indicate a response to wet weather flow; however, the peak in flow and velocity are not severe. Overall, the data quality is moderate, but will be used to establish model calibration parameters and I/I characteristics due to an absence of additional data within the catchment area.

It should be noted that there are five (5) pumping stations within the upstream catchment, which may help equalize flows. This may become important when interpreting flows and drawing conclusions from the data regarding inflow, infiltration, and sewage generation trends.

3.2.8 Flow Monitor LEX-8A (FM-005)

Flow Monitor LEX-8A (FM-005) is located along University Avenue East adjacent to the Parkview Cemetery. Data has been collected since May 15, 2013 and remained active into January 2014; the data is shown in Figure 19. This monitor is installed at the 825 mm Lexington Trunk sewer.

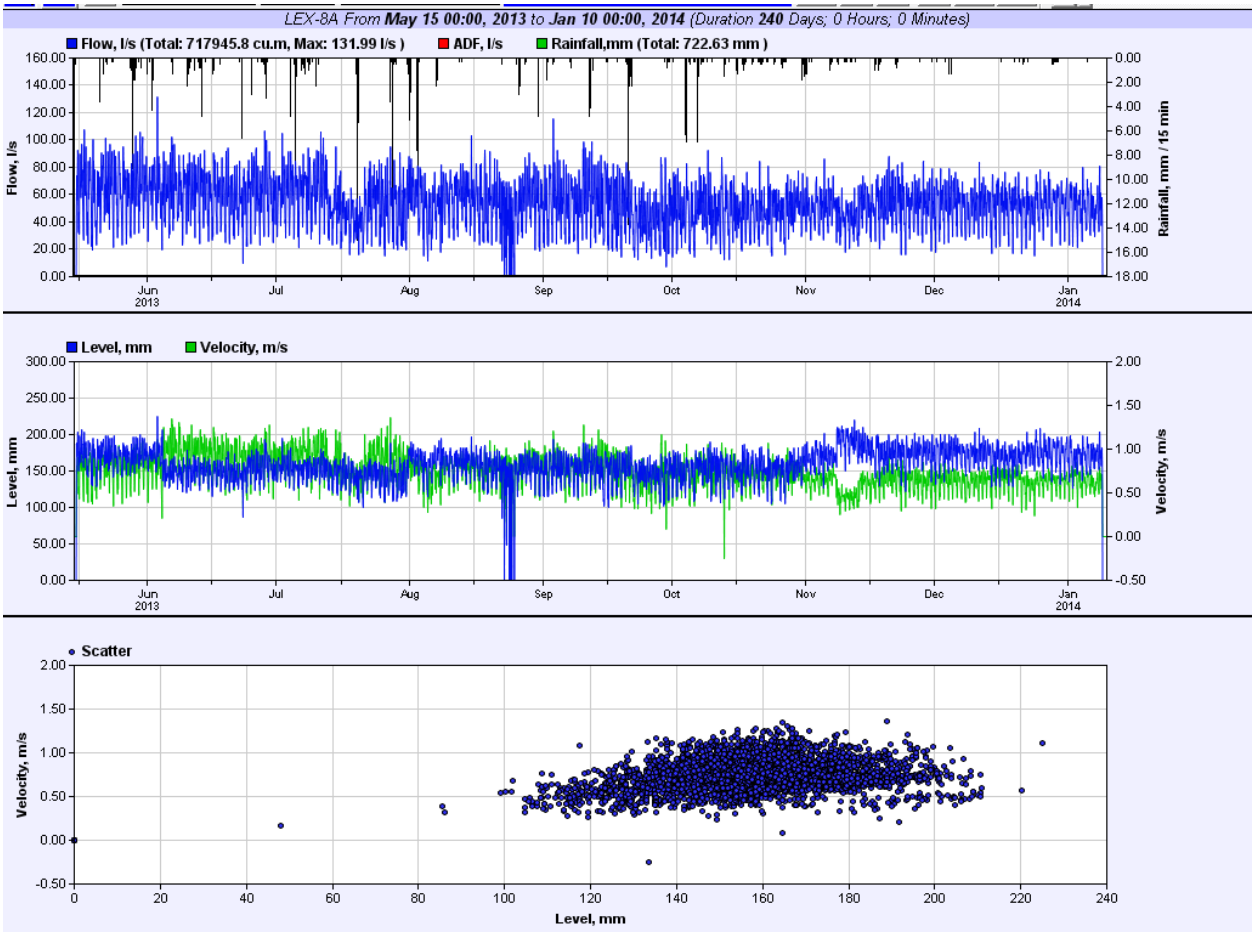


Figure 19: Raw Data Review – LEX-8A (Lexington Trunk)

The depth and velocity are relatively stable throughout this time period with some discrepancies such as the shift in average values in early June and early August. Throughout the month of August, there is a substantial missing data which will disrupt overall accuracy. This site has relatively good data quality with the exception of the missing data in august. This data may be used to establish model calibration parameters and I/I characteristics; however, the period in August with missing data should be excluded during analysis.

It should be noted that there are two pumping stations within the upstream catchment, which may help equalize flows (Bridgeport SPS and Falconridge SPS). This may become important when interpreting flows and drawing conclusions from the data regarding inflow, infiltration, and sewage generation trends.

3.2.9 Flow Monitor KEA-30 (FM-008)

Flow Monitor KEA-30 (FM-008) is located at 123 Ashberry Place. Data has been collected since December 12, 2012 and data collection ended on June 30, 2013; the data is shown in Figure 20 below. This monitor is installed at the 250 mm Keats Trunk sewer.

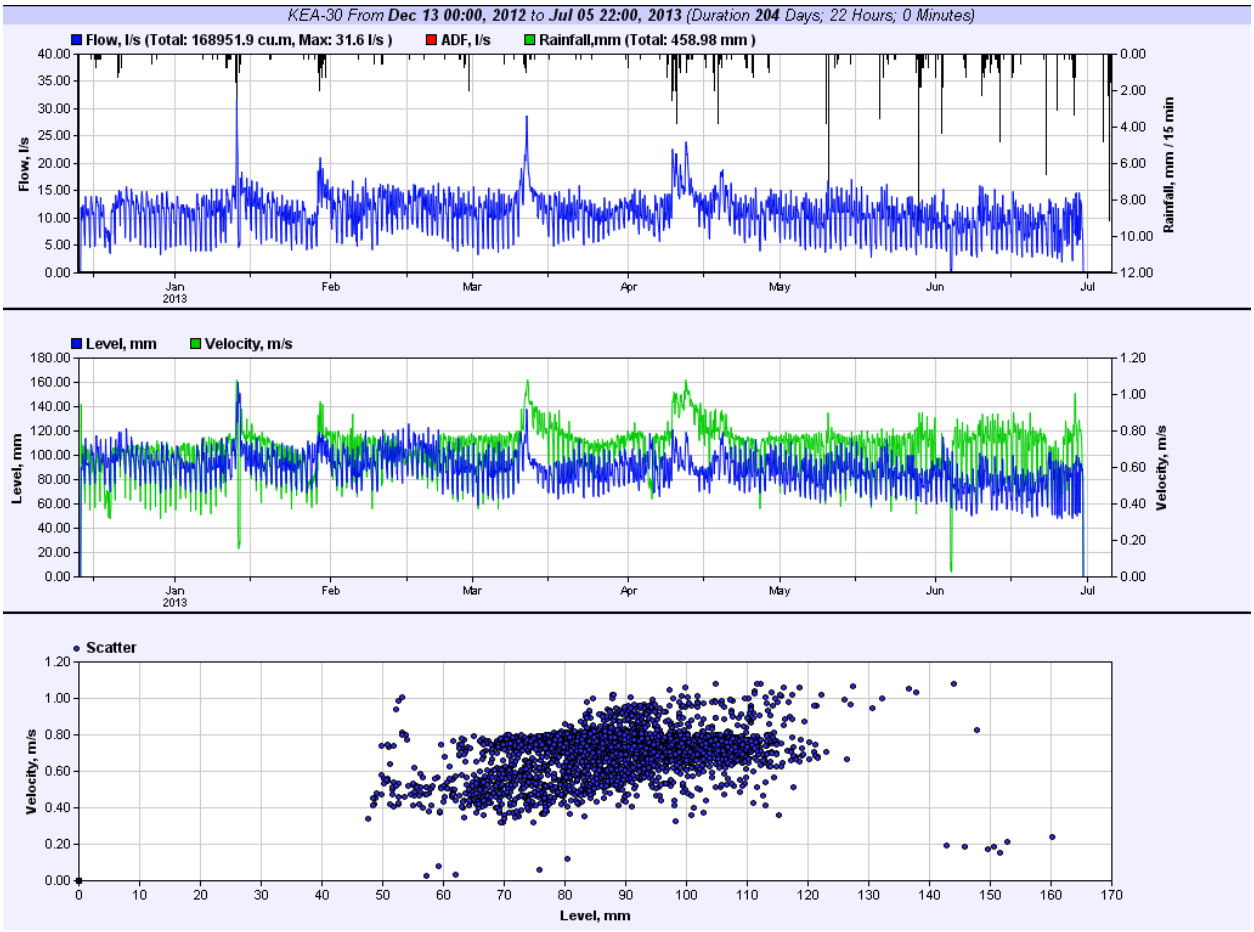


Figure 20: Raw Data Review – KEA-30 (Keats Trunk)

The scatter plot shows a moderate, but noisy, correlation between velocity and level. The peak level occurred on January 13, 2013 with a maximum depth of 160 mm, over 60% of the pipe diameter. The peaks in flow indicate a moderate response to wet weather. Overall, this site displays a moderate quality of data. It may be used to create model calibration parameters for I/I characteristics; however, may not provide the highest degree of accuracy.

3.2.10 Flow Monitor LRL-56 (FM-006)

Flow Monitor LRL-56 (FM-006) is located at Westmount Road North, just south of University Avenue, in the 750 mm Laurel Trunk sewer. Data has been collecting since May 15, 2013 and is currently still active through the end of 2013; the data is shown in Figure 21 below.

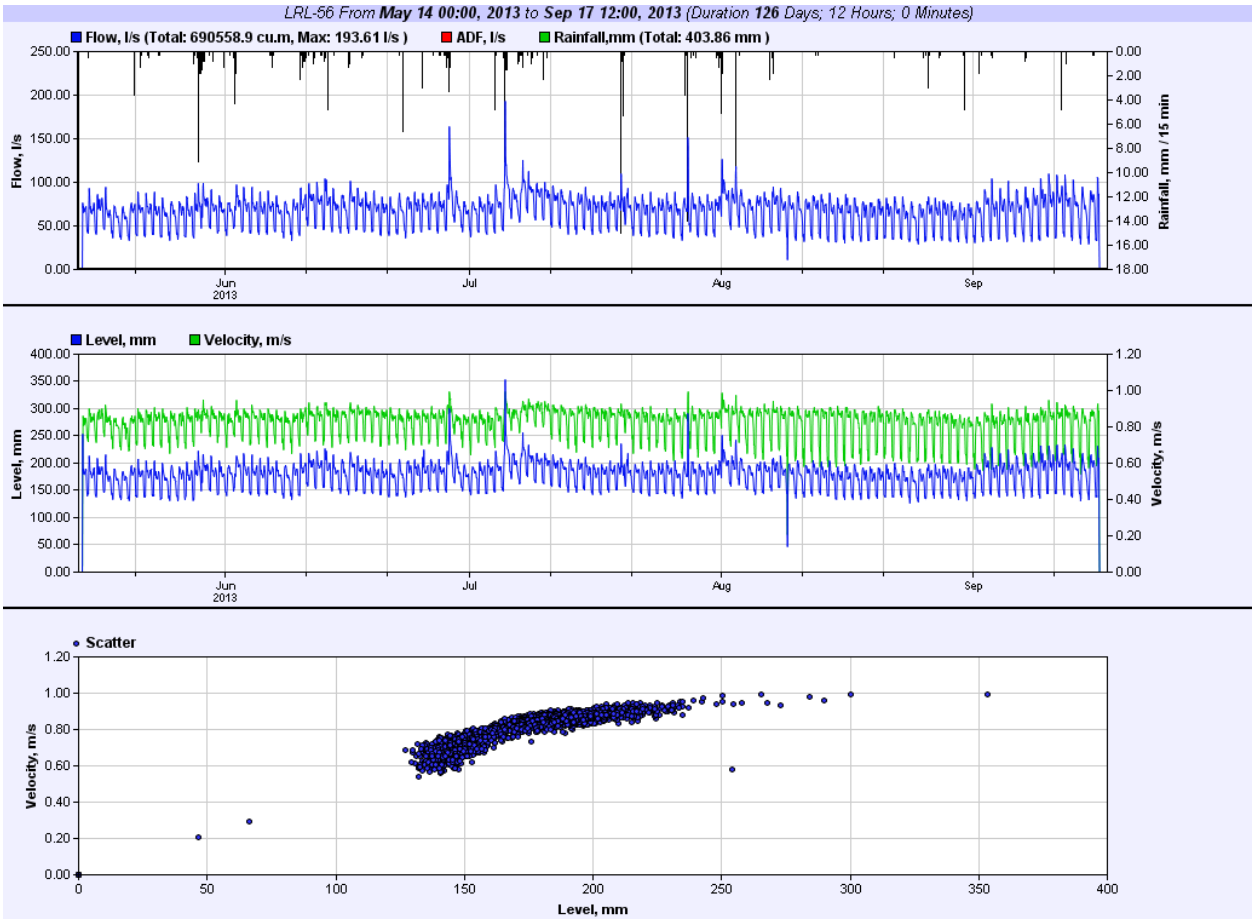


Figure 21: Raw Data Review - LRL-56 (Laurel Trunk)

The scatterplot indicates a fairly strong correlation of depth and velocity, which indicates good data quality that can be used to establish model calibration parameters and I/I characteristics. The highest peak level and flow recorded during the monitoring period occurred during the July 5 and 6 storm event resulting in a depth of 350 mm, less than 50% of the pipe diameter.

The site reveals some peaks in the level data and calculated flow data which indicates a wet weather response. However, the wet weather response appears to be limited to severe storms only.

3.2.11 Flow Monitor MPL-63 (FM-009)

Flow Monitor MPL-63 (FM-009) is located at 436 Thorndale Drive. The monitor has been collecting data since December 11, 2012 and data collection ended on July 17, 2013; the data is shown in Figure 22 below. This monitor is installed in a 300 mm Trunk sewer.

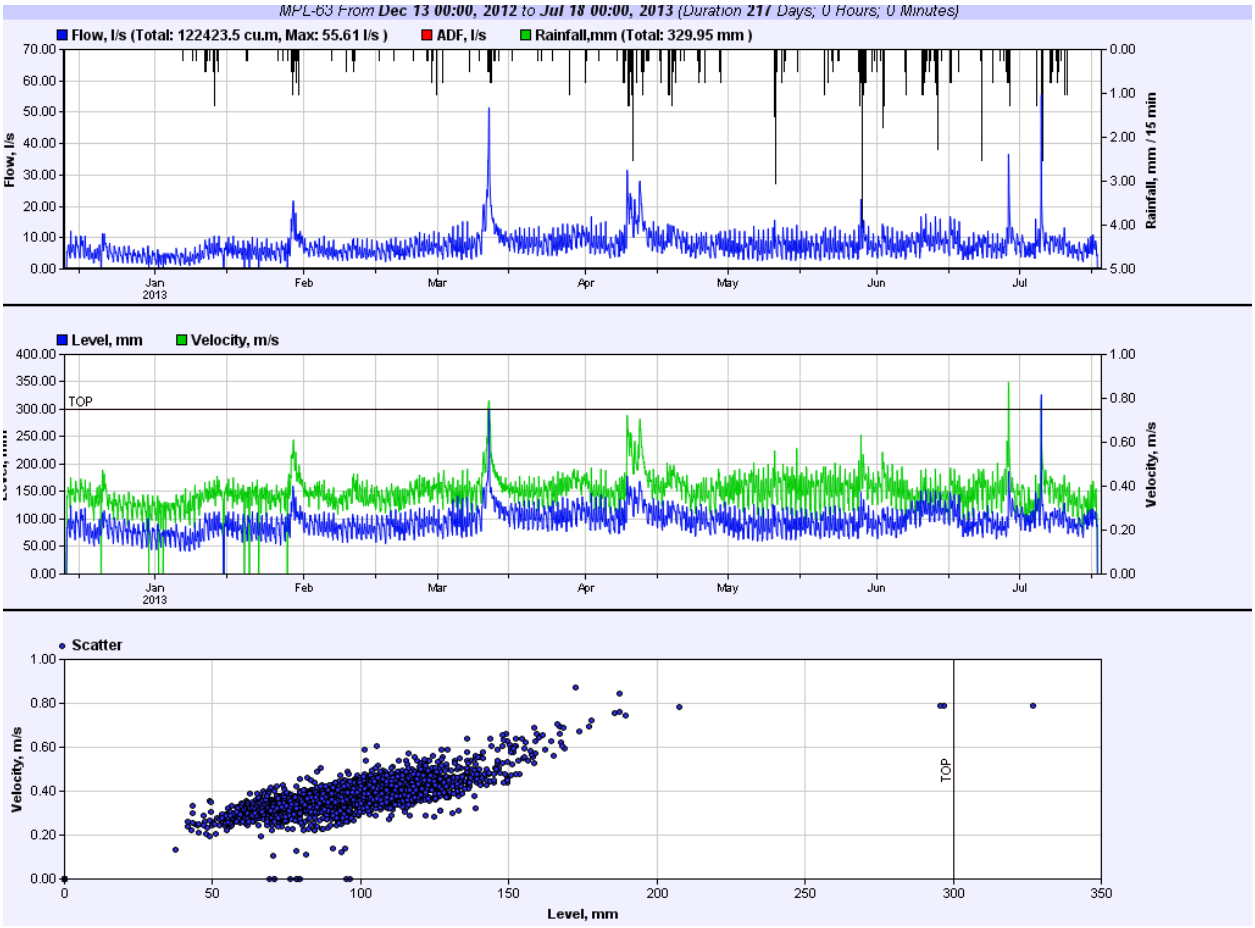


Figure 22: Raw Data Review – MPL-63

The scatterplot for this site indicates a fairly strong correlation between level and velocity, which indicates good data quality. A surcharge event occurred on July 5, 2013, during which the level reading exceeds the pipe diameter of 300 mm. The peaks in level readings indicate a moderate response to wet weather. This flow monitor site exhibits good quality data which may be used to establish model calibration parameters or I/I characteristics.

The peak level reached or exceeded the top of pipe twice in the 8 months of monitoring. The historical flow monitoring report completed by Gore and Storrie (1994) included a flow monitor in a similar area, just downstream of MPL-63; surges or excessive peaks were reported to

experience surges in the Gore and Storrie Report. The peak I/I flow was reported as 0.095 L/s/ha which is well below the allowable inflow of 0.15 L/s/ha as per the City's design guidelines.

3.2.12 Flow Monitor L31-3 (FM-010)

Flow Monitor L31-3 (FM-010) is located at 98 Peppler Street. Data has been collected since December 11, 2012 and data collection ended on June 19, 2013, the data is shown in Figure 23 below. This monitor is installed in a 250 mm sewer.

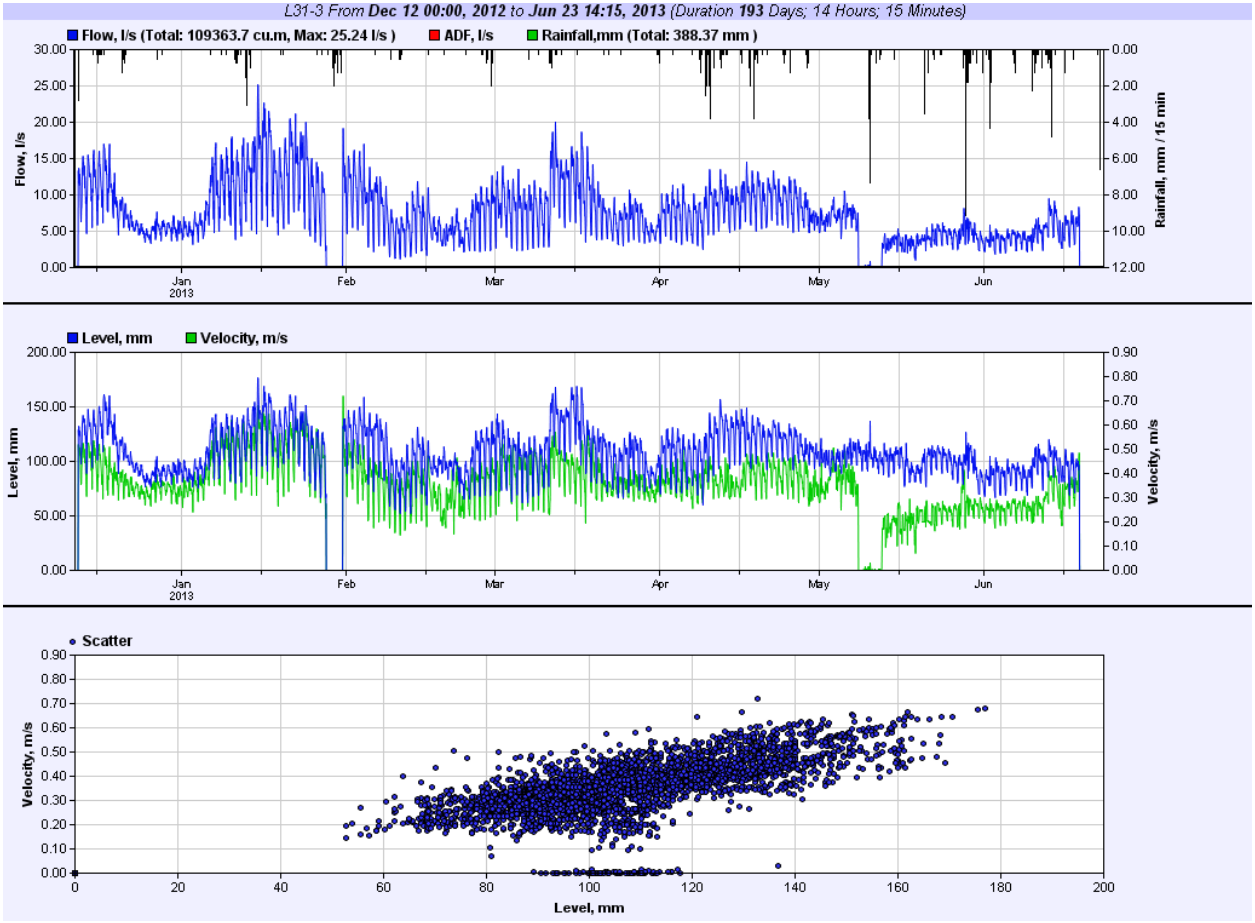


Figure 23: Raw Data Review – L31-3

The scatter plot depicts a moderate relationship between velocity and level. There is data missing at the end of January, which will be excluded in further analysis. There is a notable decrease in average velocity values in early May, this decrease in values is suspect, and may warrant further investigation. While accounting for the aforementioned deficiencies in this dataset, the site provides moderate quality data and therefore may be used to establish model calibration parameters and I/I characteristics.

3.2.13 Flow Monitor UNI-4 (FM-011)

Flow Monitor UNI-4 (FM-011) is located at 108 University Avenue East (Conestoga University, Waterloo Campus). Data has been collected since December 12, 2012 and data collection ended on July 22, 2013, the data is shown in Figure 24 below. This monitor is located in the 600 mm University Trunk sewer.

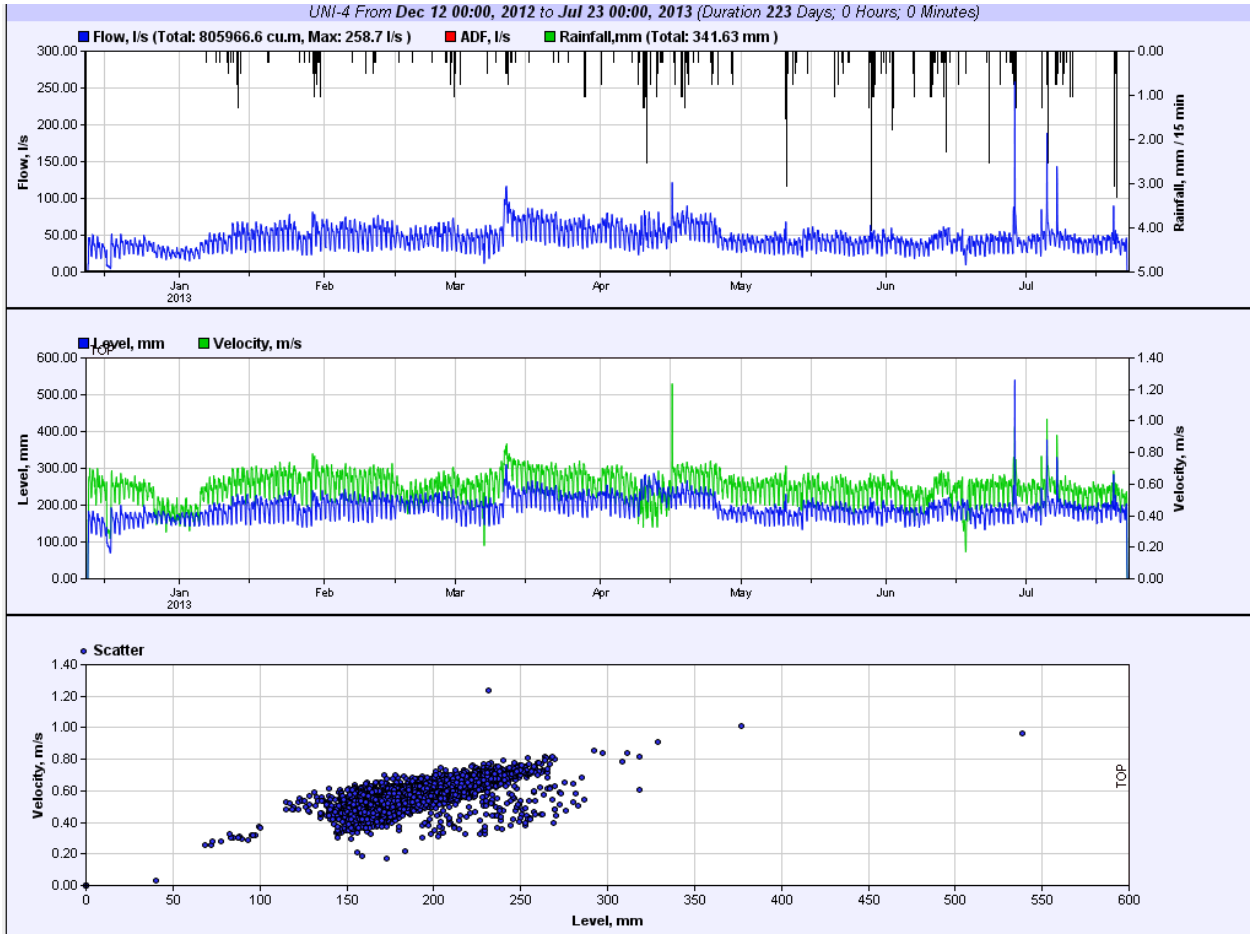


Figure 24: Raw Data Review – UNI-4 (University Trunk)

A moderate correlation of level and velocity is indicated within the scatterplot. The instantaneous peak level and velocity measurements observed in mid-April, late June, and early July, have been identified as anomalies and will be investigated during further analysis. The greatest peak level occurred at the end of June, as the depth reaches 566 mm, over 90% of the pipe diameter. With the exception of the anomalies mentioned, the quality of this data is relatively good and model calibration parameters and I/I characteristics can be established.

3.2.14 Flow Monitor LRL-19 (FM-012)

Flow Monitor LRL-19 (FM-012) is located in the park along Marshall Street. Data has been collected since December 12, 2012 and data collection ended June 24, 2013; the data is shown in Figure 25 below. This monitor is located in a 1,200 mm Laurel Trunk sewer.

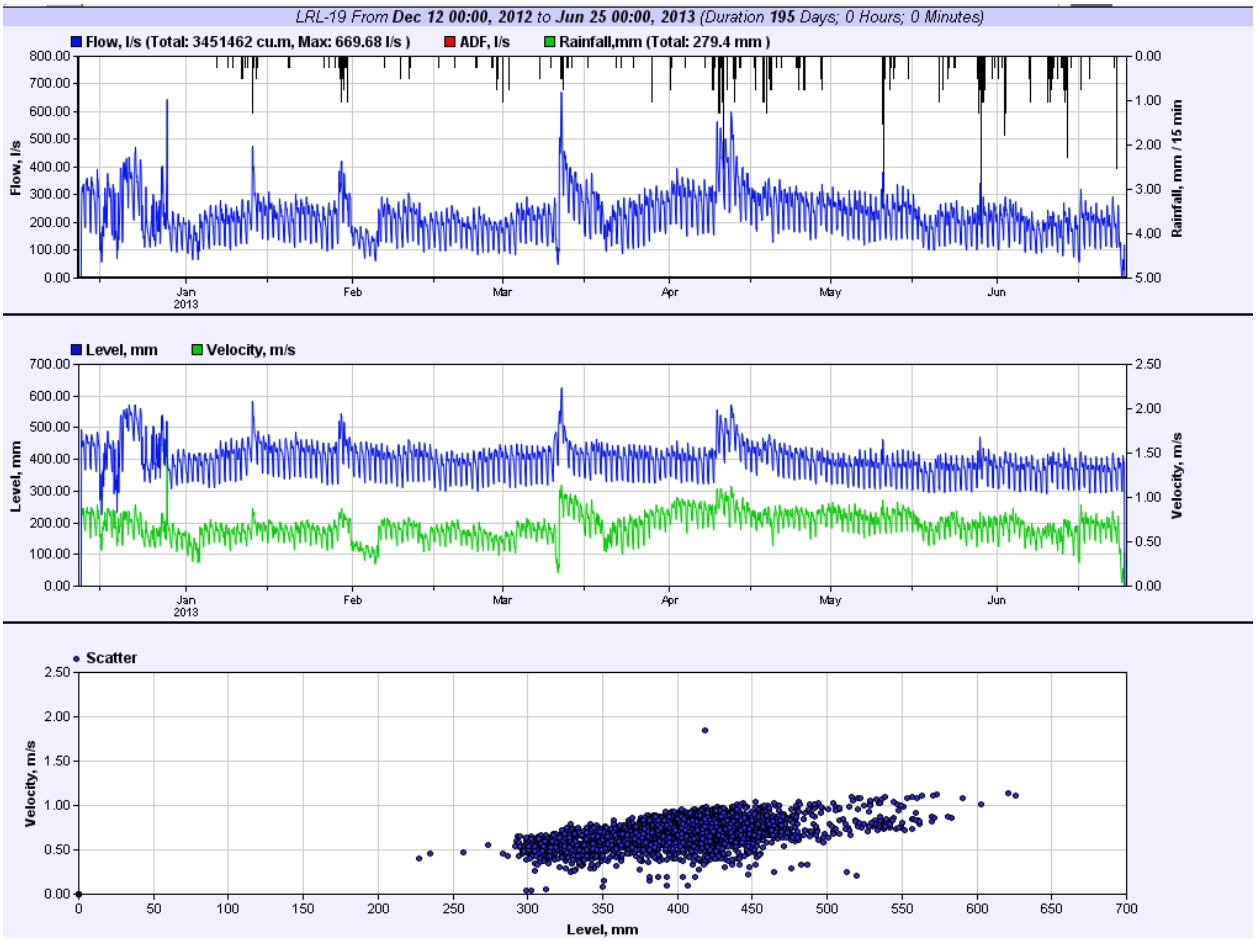


Figure 25: Raw Data Review – LRL-19

A fairly strong correlation is observed between velocity and level. The most significant outlier occurs on December 28, 2012 with a velocity of 1.79 m/s. This data point follows a short period of invalid data; therefore, this data point is suspect and will be removed prior to further analysis. Due to the increases in level and flow, it can be determined that this site exhibits wet weather responses. Overall, the data quality is relatively good and can be used to construct model calibration parameters and I/I characteristics.

3.2.15 Flow Monitor WLM-1B (FM-013)

Flow Monitor WLM-1B (FM-013) is located at the intersection of Erb Street and Regina Street. Data has been collected since June 25, 2013 and remained active into January 2014; the data is shown in Figure 26 below. This monitor is installed in the 525 mm William Trunk sewer.

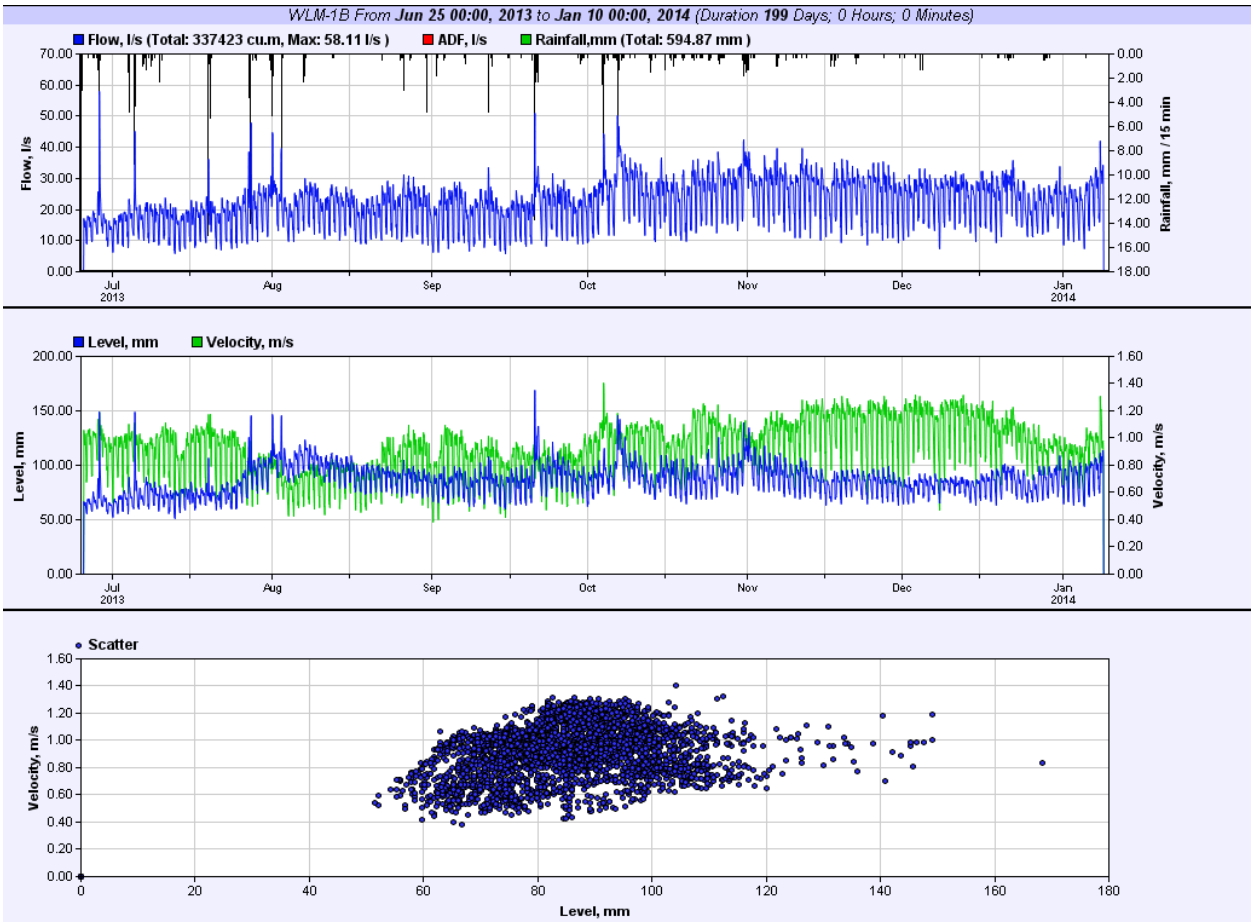


Figure 26: Raw Data Review – WLM-1B (William Trunk)

The scatter plot displays a moderate correlation between velocity and level. The level measurements exhibit various peaks, with the highest level of 160 mm occurring on September 20, 2013, which represents 30% of the pipe diameter. This site shows moderate response to wet weather. Overall, the data quality is good and can be used to construct model calibration parameters and I/I characteristics.

4.0 FUTURE FLOW MONITORING RECOMMENDATIONS

Based on the preceding review and discussion, a recommended flow monitoring program has been developed. The recommended flow monitoring program is developed based on the current monitoring program and current flow monitoring locations. The intent is to maintain the number of active flow monitors, and relocate flow monitors rather than add or remove. Many of the existing monitors are to remain in their current locations. However, four (4) locations have been identified for flow monitor relocation due to data gaps, and four (4) flow monitors have been selected for removal to allow for their redeployment in these new locations. The proposed flow monitoring plan is discussed later in this section.

4.1 USES OF FLOW MONITORING DATA

Flow monitoring data is used to develop dry weather diurnal flow patterns associated with sewage generation, as well as base flow rates. These diurnal patterns are often defined for weekdays and weekends, as the patterns can be dramatically different. The diurnal patterns represent the fluctuations in sewage generation with time, which is important in the development of a dynamic model.

Base infiltration rates are defined as the flow observed in the network, in dry weather conditions and in the absence of sewage generation. This is typically attributed to groundwater infiltration. Base flow rates are fairly consistent from day to day, but can vary dramatically with seasons. These trends in base flow can be characterized using flow monitoring data, and these trends can then be applied to the model.

The flow monitoring data will be used to characterize wet weather flows and storm response within the network. The flow monitoring data will aid in defining the fraction of precipitation that enters the sewer system during rainfall events within each catchment area. These fractions can then be applied to all storm events within the model therefore allowing estimates of wet weather contributions to sewer flows.

Once the model has been developed, the model will be calibrated and validated by comparing the model generated flows to the flow monitoring data. The calibration and validation activities can help identify and correct issues within the model.

4.2 PROPOSED LOCATIONS

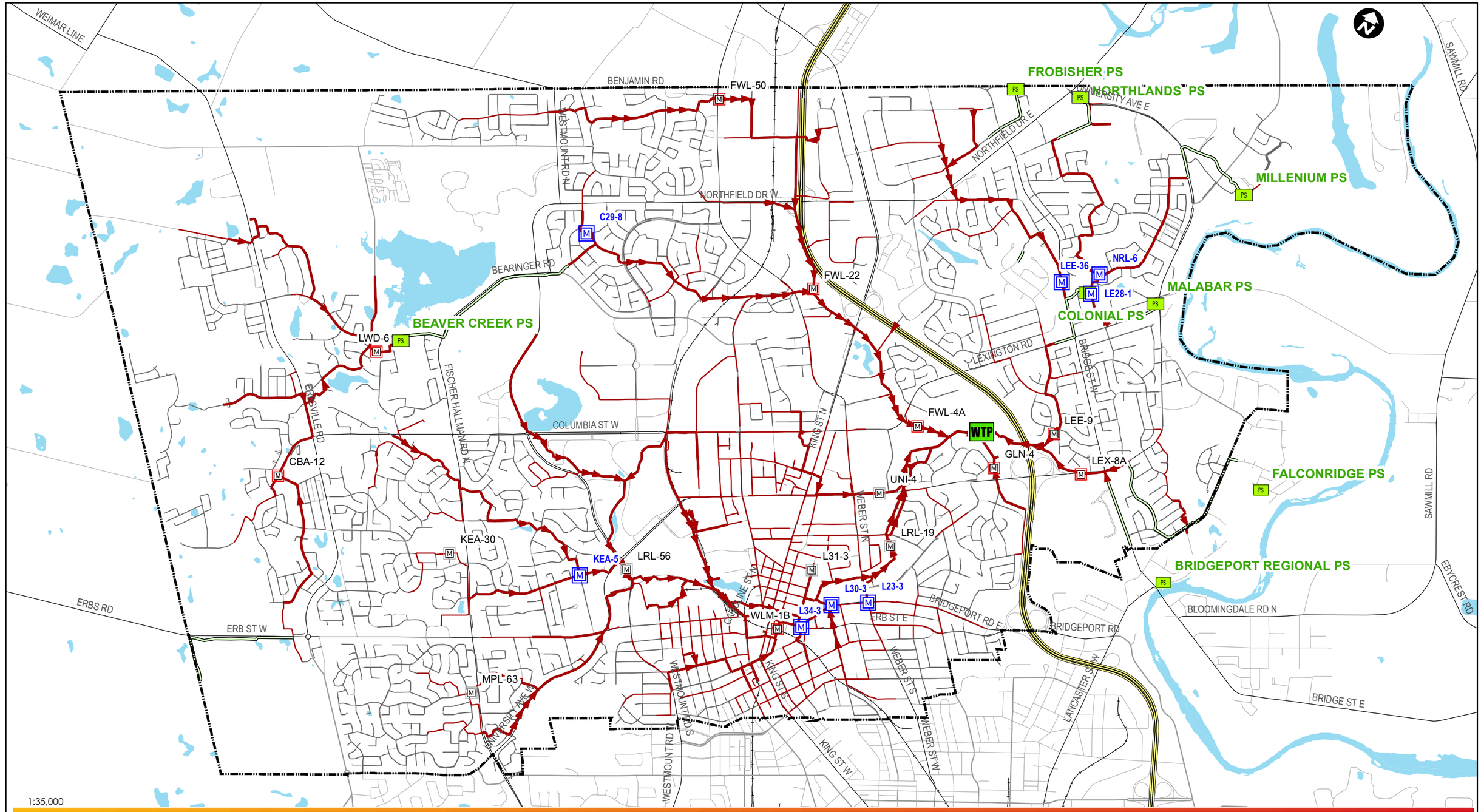
The current flow monitoring program has coverage across the entire City's sanitary network. However, Stantec recommends the relocation of four (4) flow monitors. The proposed locations for flow monitor deployment are listed below and shown in Figure 27, additional details may be found in Appendix A:

1. The Uptown Core: Additional flow monitoring is recommended within the uptown core to aid in calibration and validation of the model. The model includes local sewers in addition to trunk and subtrunk sewers. The local sewer network has been reviewed but the majority of the inverts have not been verified by drawing review or field inspection due to project budget and time constraints.

   Therefore, three (3) monitors have been proposed within the uptown core area (L23-3, L30-3, and L34-3). The catchment areas associated with these monitors overlap due to bifurcation. These additional flow monitors would be useful in validating the model, and potentially identifying connectivity issues in this important part of the Master Plan. Depending on the data captured, one (1) or more of the sites may be useful in characterizing inflow and infiltration contributions in this old part of the system.

2. Upstream of Colonial SPS: Three (3) flow monitors are proposed for installation upstream of Colonial SPS, within the Lee Trunk catchment area. The Lee Trunk catchment area contains five (5) pump stations, and only one (1) flow monitor is currently installed (LEE-9). The effects that the pump stations have on the downstream flows are not well known. It will be difficult to validate the modelled flows in areas upstream of the pumping stations because the only flow monitor (LEE-9) is at the outlet of the catchment, downstream of the five (5) pump stations. Of the five (5) pumping stations within this catchment, Colonial SPS receives flows the largest catchment area, therefore it is assumed to have the greatest impact on the downstream flows. The deployment three (3) flow monitors is therefore recommended for the catchment areas upstream of the Colonial SPS (PROP-04, PROP-05, and PROP-06).

3. Clair Trunk: Historically, I/I concerns have been identified along the Clair Trunk. The current flow monitor (LRL-56) downstream of this area captures a large area, encompassing the Clair sewershed. The Clair Sewershed Study was completed by Stantec in 2002, which was focused within the proposed area. During this study, it was noted that precipitation volumes were abnormally low therefore flows observed may not have represented typical wet weather responses. It is therefore recommended that a monitor be placed along the Clair Trunk (PROP-07).



1:35,000

1611-11191

Stantec

Stantec Consulting Ltd.
49 Frederick Street
Kitchener, Ontario, Canada
N2H 6M7
Tel: (519) 579-4410
Fax: (519) 579-6733
www.stantec.com

Legend

Transportation Network
- Arterial
- Collector
- Highway
- Local
- CityBoundary

Water Body
- PS — Existing Pump Station
- Forcemain
- WTP — Wastewater Treatment Plant

All Sanitary Sewers
- Local Sewers
- Trunk Sewers

Model Selection Set
- Local Sewers
- Trunk Sewers

Current Flow Monitors
- M — Existing Monitors
- M — Existing Monitors (Removed)
- M — Proposed Monitor Location

Figure No. FIG-27

Title **PROPOSED FLOW MONITOR RELOCATIONS**

Client/Project CITY OF WATERLOO SANITARY SERVICING MASTER PLAN UPDATE

4. Cedar Trunk: The Cedar Trunk has been identified as observing extraneous flows in the 1994 Gore and Storrie Study. Additionally, the 2013 flow monitoring data indicates an increase in extraneous flows between the Laurelwood Trunk (LWD-6) and the Forwell Trunk (FWL-4A). Therefore it is recommended that a flow monitor be installed a sub trunk connected to the Cedar Trunk (PROP-08). Additional information regarding wet weather responses for this area will aid in the characterization of wet weather flows, and it will aid in the calibration and validation of flows within this area.

To maintain the number of deployed flow monitors, eight (8) existing flow monitors are to be removed prior to installation of the proposed flow monitors. Two (2) existing flow monitors are to remain deployed: Middle Forewell (FWL-22) and Upper Forewell (FWL-50).

4.3 SUMMARY

Flow monitoring data is used to quantify diurnal flow patterns, wet weather flow, and to validate the model. A flow monitoring program is currently underway with AGM, which captures nearly the entire network. Stantec recommends the redeployment of 8 of the 10 flow monitors in order to collect some additional information in particular areas.

The eight (8) proposed flow monitor locations for new deployment include:

1. The Downtown Core (PROP-01, PROP-02, PROP-03).
2. Upstream of Colonial SPS (PROP-04, PROP-05, PROP-06).
3. The Cedar Trunk (PROP-07).
4. The Clair Trunk (PROP-08).

All existing flow monitors are to be removed with the exception of FWL-22 and FWL-50.

5.0 RECOMMENDATIONS FOR THE I/I REDUCTION PROGRAM

5.1 PREVIOUS EFFORTS

A number of I/I studies have been completed since 1989, including the Gore and Storrie Study, which clearly demonstrated that the areas where the I/I component was significant were built prior to the 1980 by-law prohibiting roof leader, sump pump, cellar drain and weeping tile connections to the sanitary sewers.

A number of initiatives were identified in the 2002 WSSS MP Update. The majority of the I/I into the system was believed to enter the system via roof leader and/or foundation drain connections. The installation of sump pumps and downspout disconnection, combined with lot grading improvements, have been recommended as potential measures to reduce extraneous flow.

A pilot project was conducted in the Clair Trunk which included flow monitoring and CCTV inspections. Significant levels of extraneous flow were not identified through this study.

5.2 SEWER USE BYLAW (BY-LAW NO. 09-059)

The City of Waterloo currently enforces By-Law No. 09-059, which came into force in 2009, regarding sewage and stormwater services. This By-Law outlines the use of the sewage and stormwater collection system, including connections, maintenance, and billing practices. The By-Law also discusses the Municipality's authority to enforce these rules.

As an effort to reduce extraneous flows, foundation drains, roof drains, eaves troughs and all drains which collect stormwater shall not discharge into sewage services, with exceptions discussed within the By-Law.

According to the Municipal Act (2001), the Municipality may enter an Owner's property to determine whether the public utility is being unlawfully used. In addition, if an Owner fails to connect their building(s) to services in accordance with this By-Law, the City may enter the property of the Owner to fix the problem.

5.3 STATE OF THE INDUSTRY

Within Ontario Municipalities, Sewer Use By-Laws are used to prevent connection of foundation drains, downspouts, and sump pumps to the wastewater collection system for new construction, and to promote disconnection from existing development. Active enforcement of Sewer Use By-Law is critical; enforcement includes actively pursuing the reduction or elimination of sources that discharge storm or uncontaminated water into the sanitary sewer system.

Downspout Disconnection Programs have been enacted in other Municipalities within Southern Ontario. These programs provide education to customers about the impact of downspout connections and are given information on how to disconnect their downspouts from the sanitary sewer system. Efforts often include weeping tile disconnects/sump pump systems, and the installation of backwater valves, in addition to downspout disconnections. Some Municipalities have enacted programs to assist funding for the removing downspouts for customers.

5.4 RECOMMENDATIONS

Prior to implementing an I/I reduction program, the goals of the program should be identified. It is recommended that a clear process be developed which would outline field programs to identify areas of concern, and implementation strategies to reduce I/I within these areas. It is recommended that some management components be included in the program to ensure effective implementation. Some guidelines are outlined below, including some key features which may be included in the I/I reduction program.

5.4.1 Identification of Drivers

- Capacity at wastewater treatment plant and cost of treating wastewater
- Capacity within the collections network
- Flooding and sewer back-up concerns

5.4.2 Identification of Focus Areas

5.4.2.1 Field Programs

- Flow Monitoring
- CCTV Investigations
- Smoke Testing
- Die Testing

5.4.2.2 Desktop Studies

- Modified RTK Model Analysis

5.4.3 Implementation

5.4.3.1 Field Programs

Private Side:

- Downspout Disconnect
- Backflow Preventer Installation
- Weeping Tile Drain Assessments
- Sump Pump Installation

Public Side:

- Rehabilitation (Grouting, Slip-Lining, etc.)
- Replacement of Ageing Infrastructure

5.4.3.2 Pilot Studies

- Clair Sewershed is currently undergoing a Pilot Study, as recommended in the 2002 SSMP.

5.4.3.3 Policies, Education, and Funding Opportunities

- Policies encouraging Downspout Disconnect, Backflow Prevention, etc.
- Subsidies to residents for Downspout Disconnect, Backflow Prevention, etc.
- Educational Pamphlets discussing the importance of Downspout Disconnect, Backflow Prevention, Proper Site Grading.

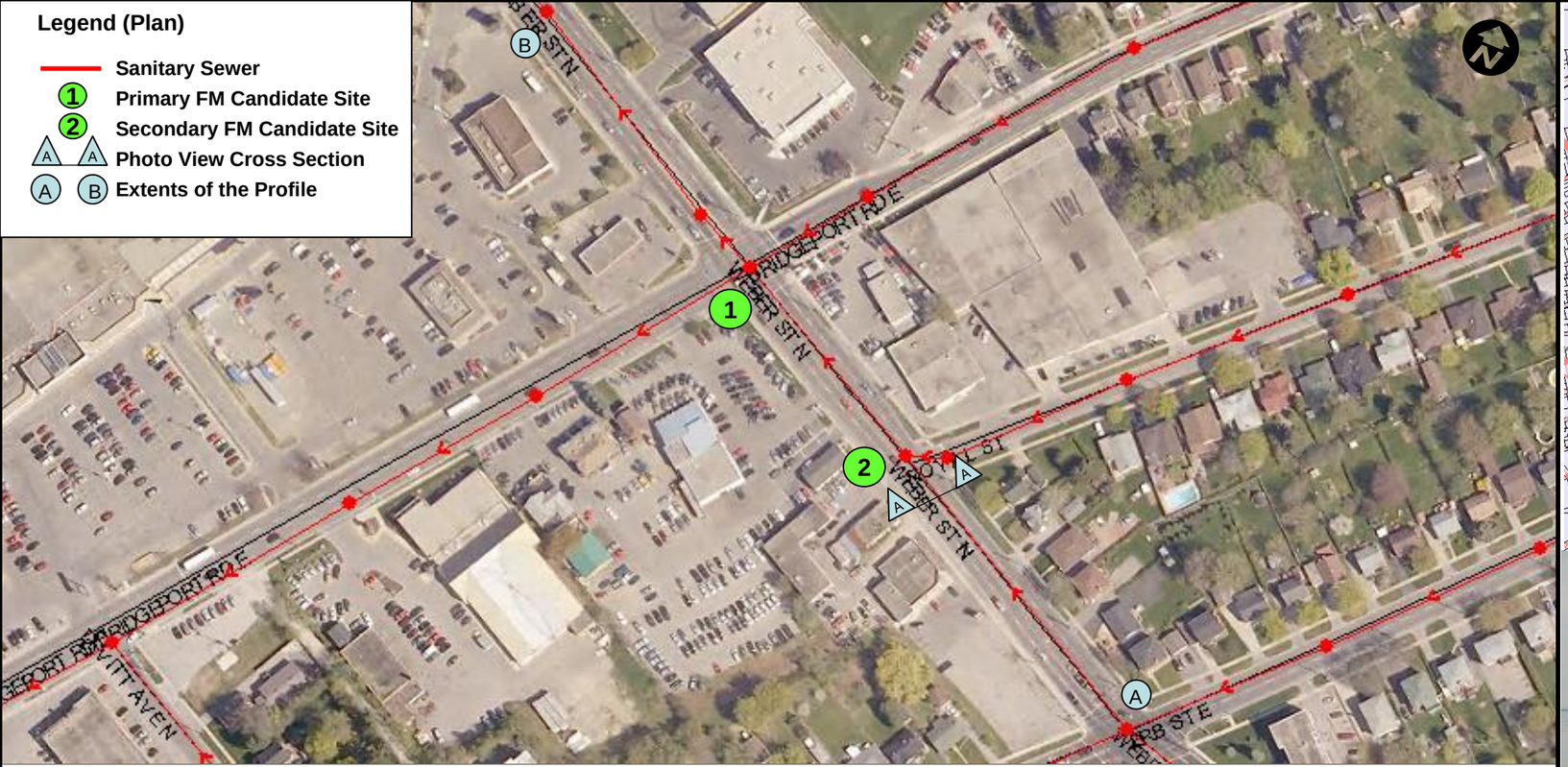
5.4.4 Management System

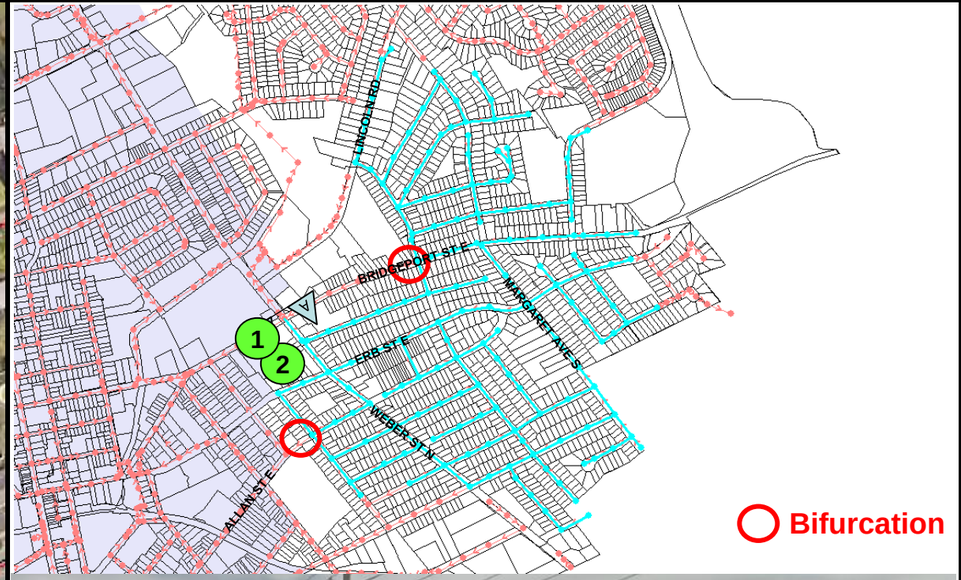
- Central Database for all Flow Monitoring and Field Data.
- Program including well defined triggers, pathways, and milestones.
- Designate a single staff member or team of staff members to carry out the program.

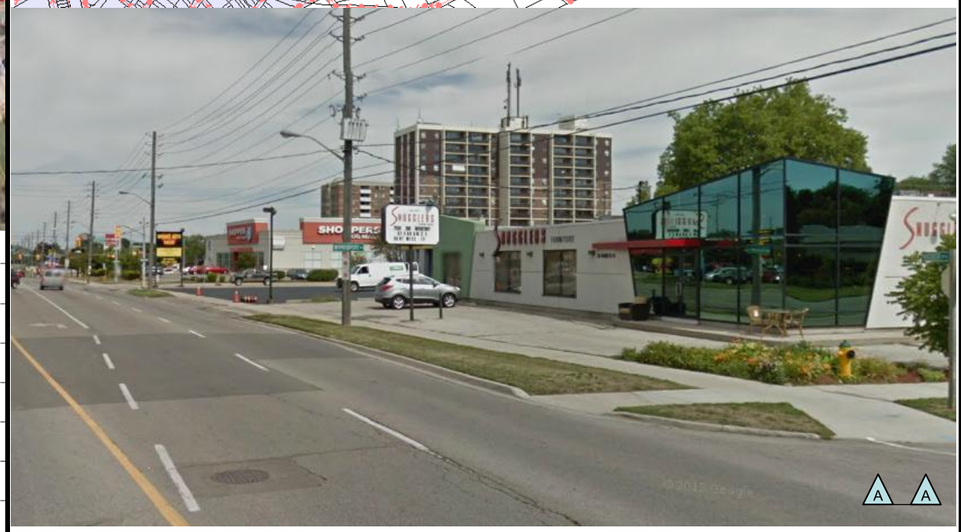
APPENDIX A: PROPOSED FLOW MONITORING LOCATIONS

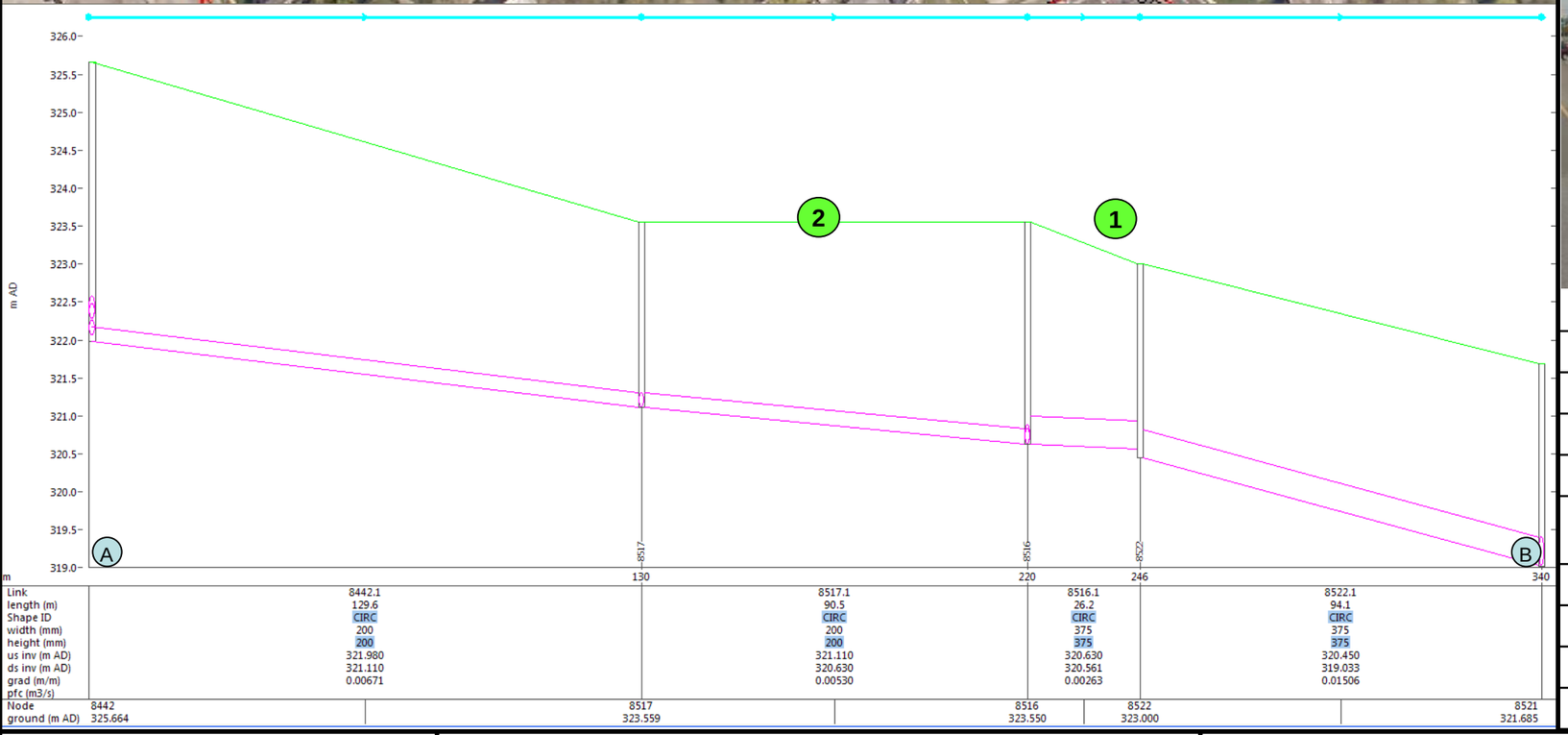
Legend (Plan)

- Sanitary Sewer
- 1 Primary FM Candidate Site
- 2 Secondary FM Candidate Site
- A A Photo View Cross Section
- A B Extents of the Profile









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height (mm)	200	200	375	375
us inv (m AD)	321.980	321.110	320.630	320.450
ds inv (m AD)	321.110	320.630	320.561	319.033
grad (m/m)	0.00671	0.00530	0.00263	0.01506
pfc (m3/s)				
Node	8442	8517	8516	8522	8521
ground (m AD)	325.664	323.559	323.550	323.000	321.685

Location Details

	Primary 1	Secondary 2
MH ID	L23-3 (8516)	L23-4A (8517)
Upstream Diameter (mm)	200	200
Upstream Slope (%)	0.530	0.671
Downstream Diameter (mm)	375	200
Downstream Slope (%)	0.263	0.530
Drainage Area (ha)	106	106
Depth to Bottom (m)	2.9	2.4
Accessibility	On Road	On Road

Stantec

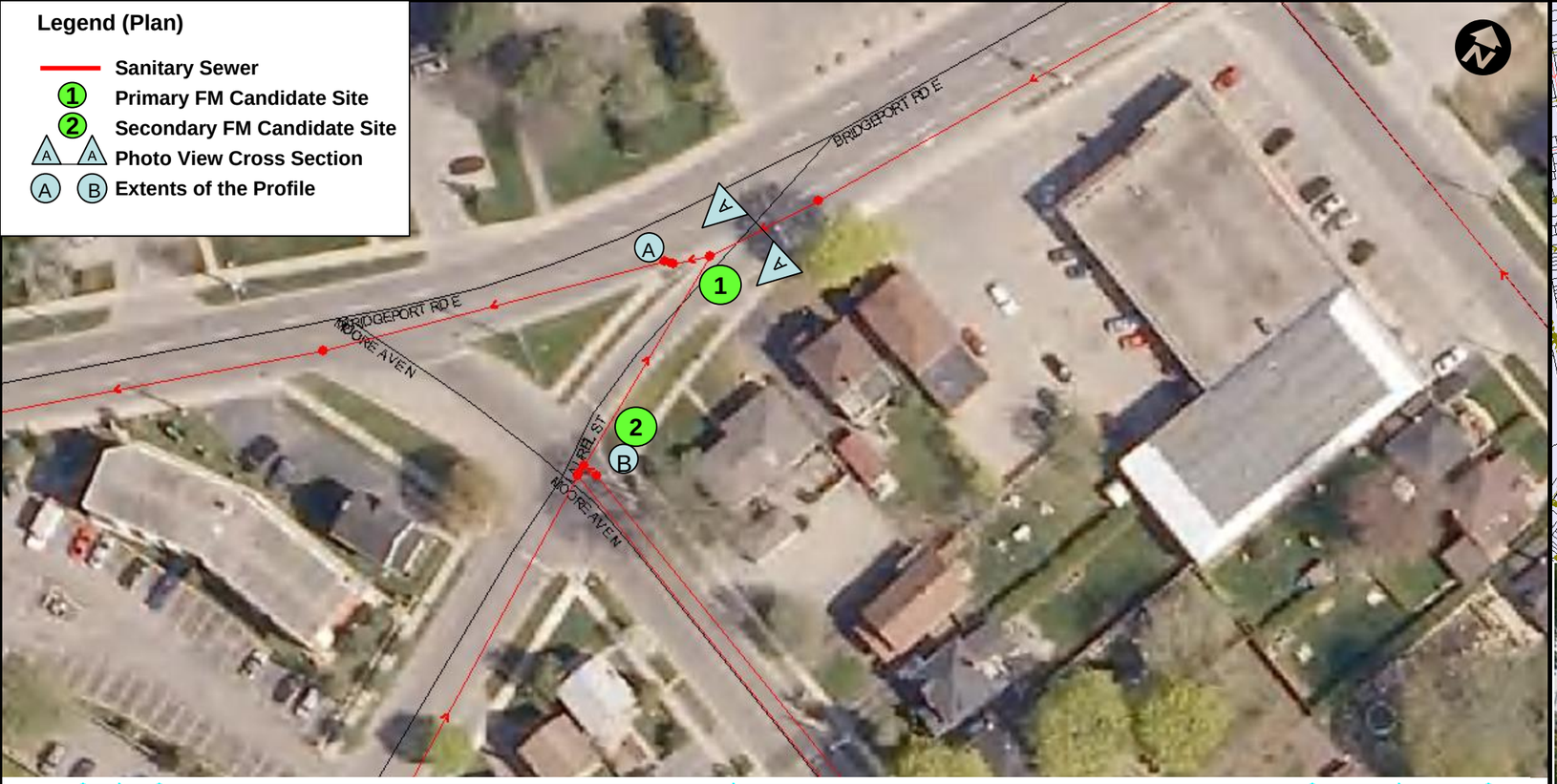
Waterloo Sanitary Master Plan Updates

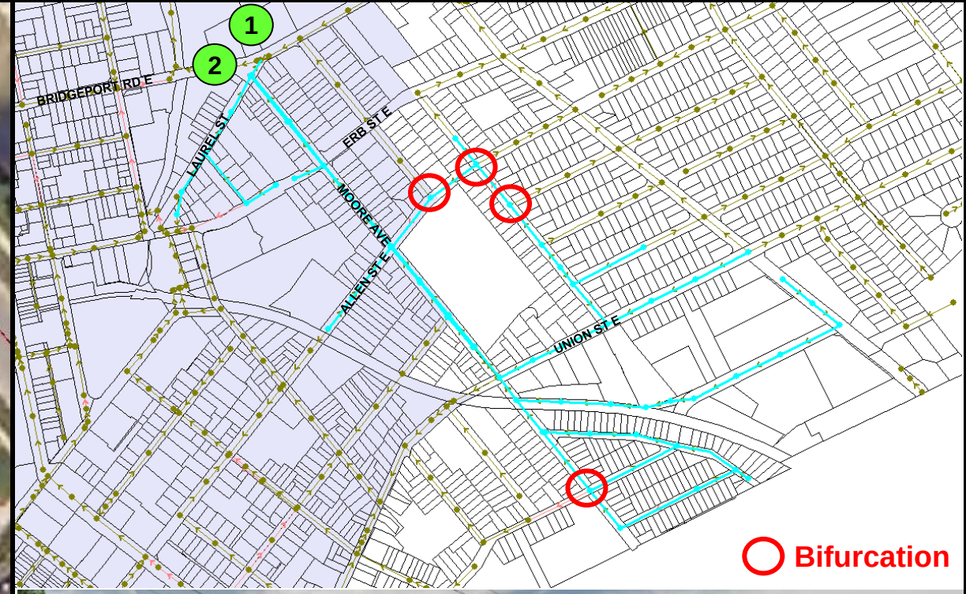
Monitor: L23-3
Location: The Uptown Core
Weber Street and Bridgeport Street

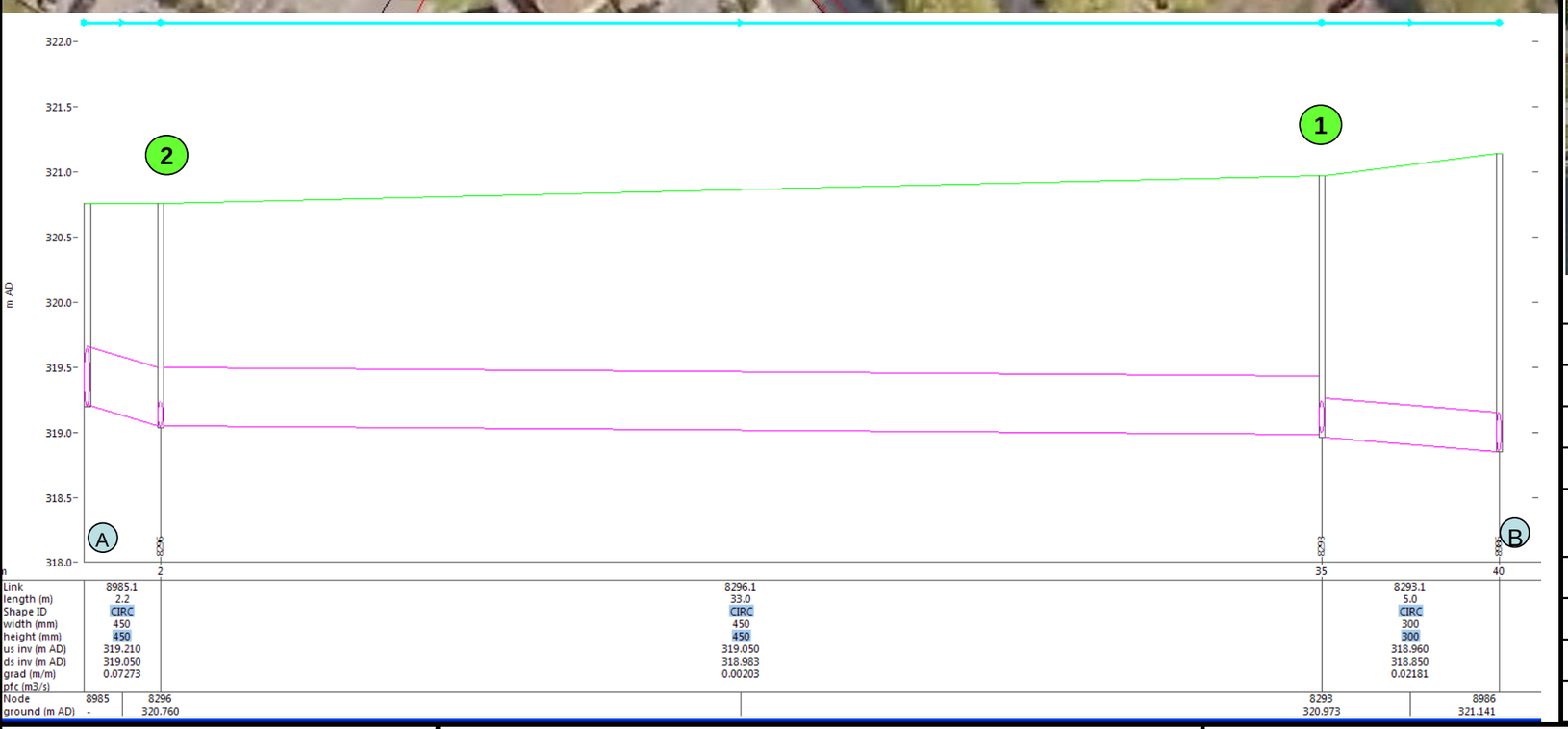
Scale: NTS

Date: March 2014

Figure: A1







Location Details

	Primary 1	Secondary 2
MH ID	L30-3 (8293)	L30-11 (8296)
Upstream Diameter (mm)	450	450
Upstream Slope (%)	0.203	7.27
Downstream Diameter (mm)	300	450
Downstream Slope (%)	2.181	0.203
Drainage Area (ha)	38	38
Depth to Bottom (m)	2.0	1.7
Accessibility	On Road	On Road

Stantec

Waterloo Sanitary Master Plan Update

Monitor: L30-3
Location: The Uptown Core
Moore Street

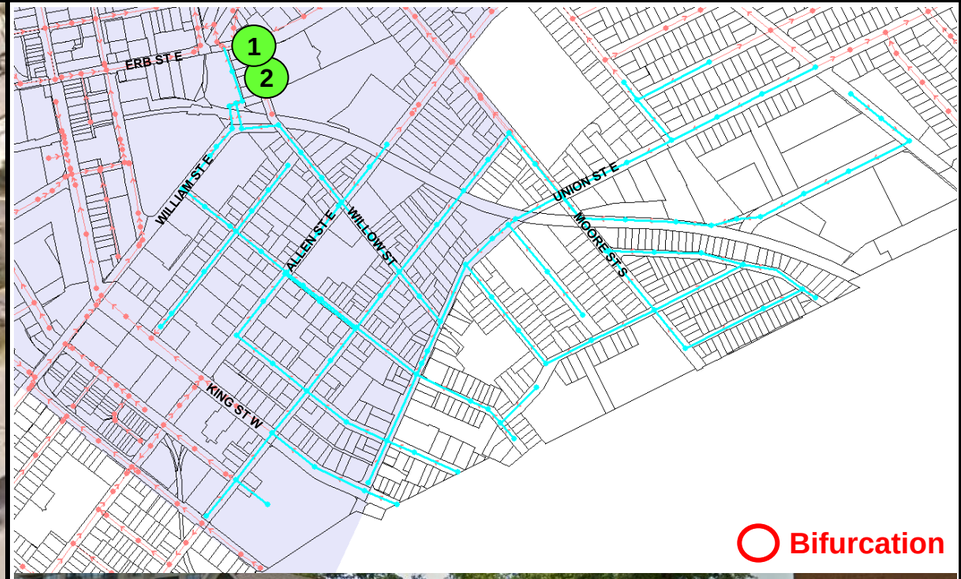
Scale: NTS

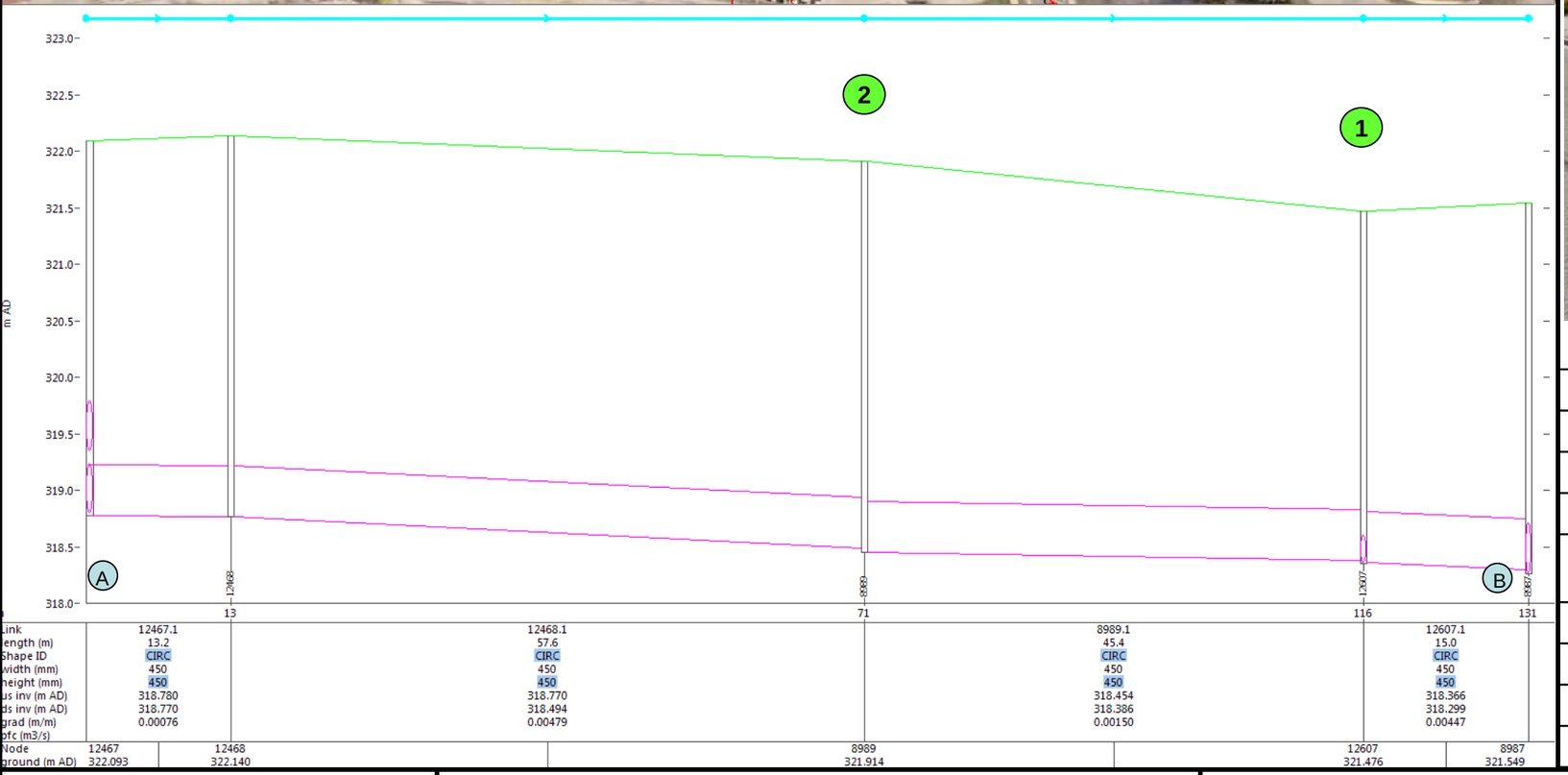
Date: March 2014

Figure: A2

Legend (Plan)

- Sanitary Sewer
- 1 Primary FM Candidate Site
- 2 Secondary FM Candidate Site
- A A Photo View Cross Section
- A B Extents of the Profile





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Height (mm)	450	450	450	450
us inv (m AD)	318.780	318.770	318.454	318.366
ds inv (m AD)	318.770	318.494	318.386	318.299
grad (m/m)	0.00076	0.00479	0.00150	0.00447
Qfc (m3/s)				
Node	12467	12468	8989	12607	8987
Ground (m AD)	322.093	322.140	321.914	321.476	321.549

Location Details

	Primary 1	Secondary 2
MH ID	L34-3 (12607)	L34-3A (8989)
Upstream Diameter (mm)	450	450
Upstream Slope (%)	0.150	0.479
Downstream Diameter (mm)	300	450
Downstream Slope (%)	0.447	0.076
Drainage Area (ha)	63	63
Depth to Bottom (m)	3.1	3.4
Accessibility	On Roadway	On Private Driveway

Stantec

Waterloo Sanitary Master Plan Upgrade

Monitor: L34-3
Location: The Uptown Core
Erb Street East at Peppler Street

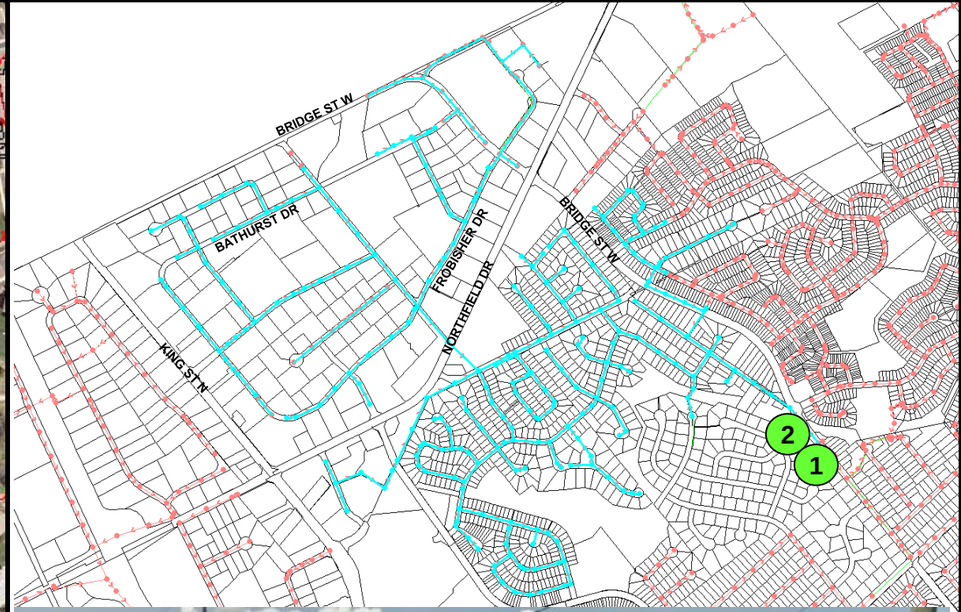
Scale: NTS

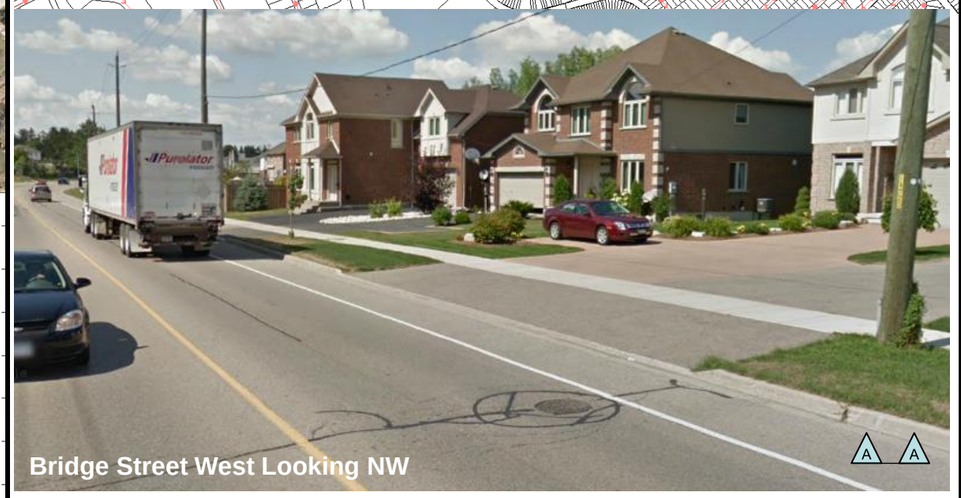
Date: March 2014

Figure: A3

Legend (Plan)

- Sanitary Sewer
- 1 Primary FM Candidate Site
- 2 Secondary FM Candidate Site
- A A Photo View Cross Section
- A B Extents of the Profile





Link	12054.1	12049.1	10356.1	10357.1	15504.1	10359.1
length (m)	80.0	81.1	84.9	10.8	74.7	76.4
Shape ID	CIRC	CIRC	CIRC	CIRC	CIRC	CIRC
width (mm)	525	525	600	600	600	600
height (mm)	525	525	600	600	600	600
us inv (m AD)	326.978	326.739	326.304	326.000	325.950	325.715
ds inv (m AD)	326.741	326.484	326.031	325.950	325.775	325.500
grad (m/m)	0.00296	0.00314	0.00322	0.00463	0.00234	0.00281
pfc (m3/s)						
Node	12054	12049	10356	10357	15504	10359	10358
ground (m AD)	334.136	333.663	331.584	329.231	330.150	329.435	330.270

Location Details

	Primary 1	Secondary 2
MH ID	LEE-36 (10359)	LEE-36A (15504)
Upstream Diameter (mm)	600	600
Upstream Slope (%)	0.234	0. 463
Downstream Diameter (mm)	600	600
Downstream Slope (%)	0.234	0.234
Drainage Area (ha)	163	163
Depth to Bottom (m)	3.7	4.2
Accessibility	On Road	On Road

Stantec

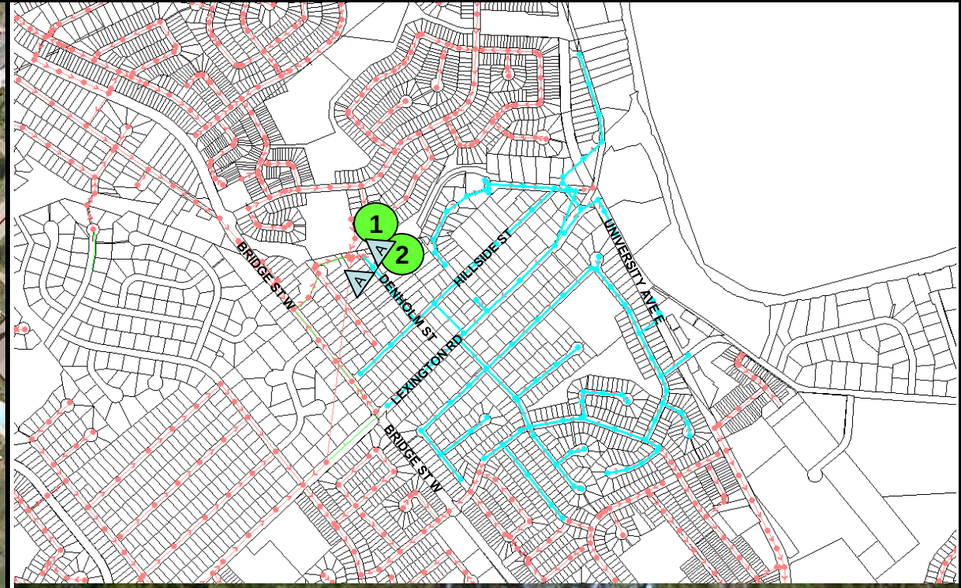
Waterloo Sanitary Master Plan Update

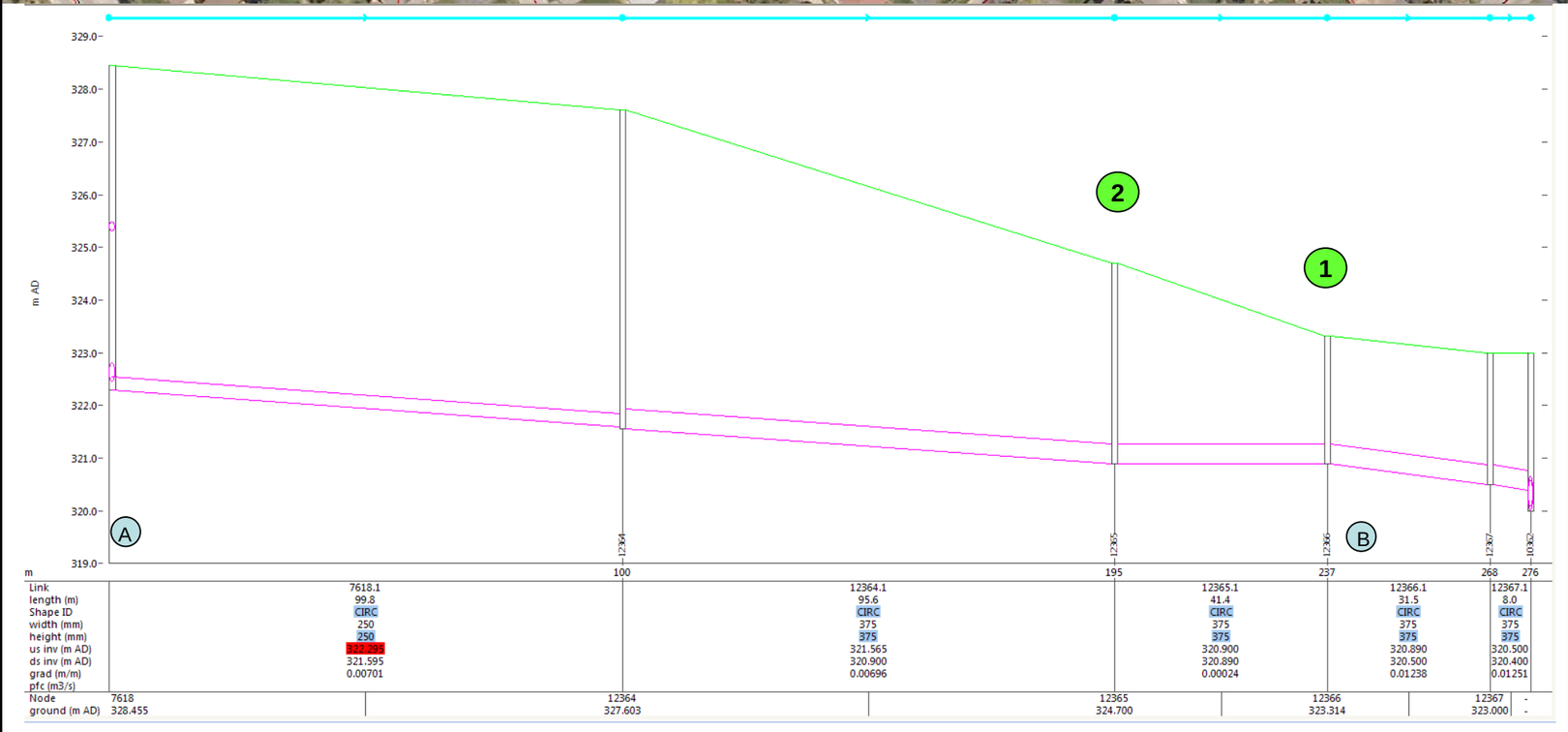
Monitor: LEE-36
Location: Upstream of Colonial SPS
Bridge Street West

Scale: NTS

Date: March 2014

Figure: A4





Location Details

	Primary 1	Secondary 2
MH ID	LE28-1 (12366)	LE28-2 (12365)
Upstream Diameter (mm)	375	375
Upstream Slope (%)	1.238	0.696
Downstream Diameter (mm)	375	375
Downstream Slope (%)	1.238	1.238
Drainage Area (ha)	61	61
Depth to Bottom (m)	2.4	3.8
Accessibility	On SPS Access Road	On SPS Access Road

Stantec

Waterloo Sanitary Master Plan Update

Monitor: LE28-1
Location: Upstream of Colonial SPS Denholm Street West

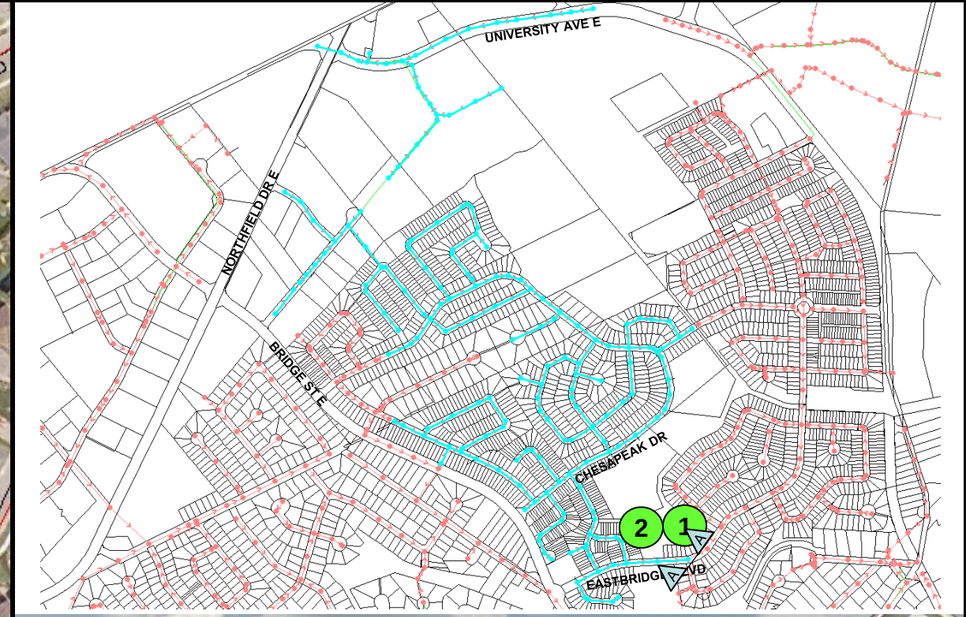
Scale: NTS

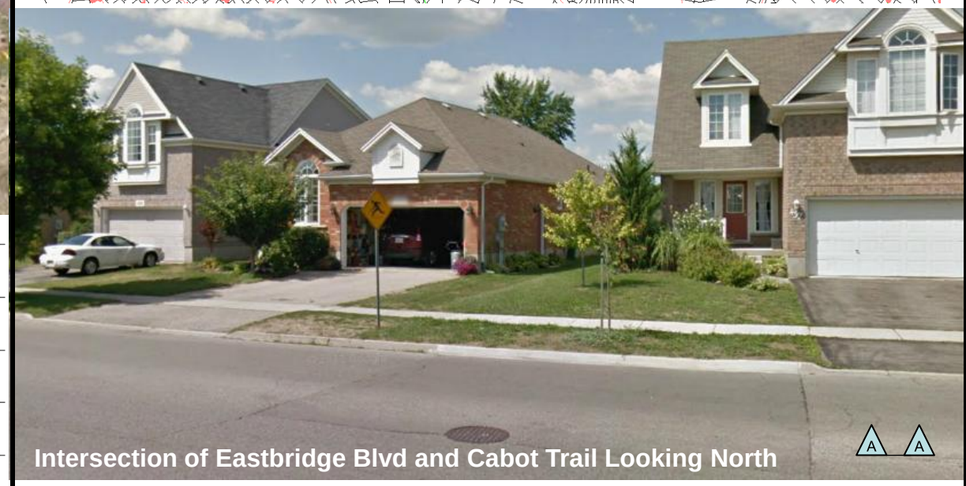
Date: March 2014

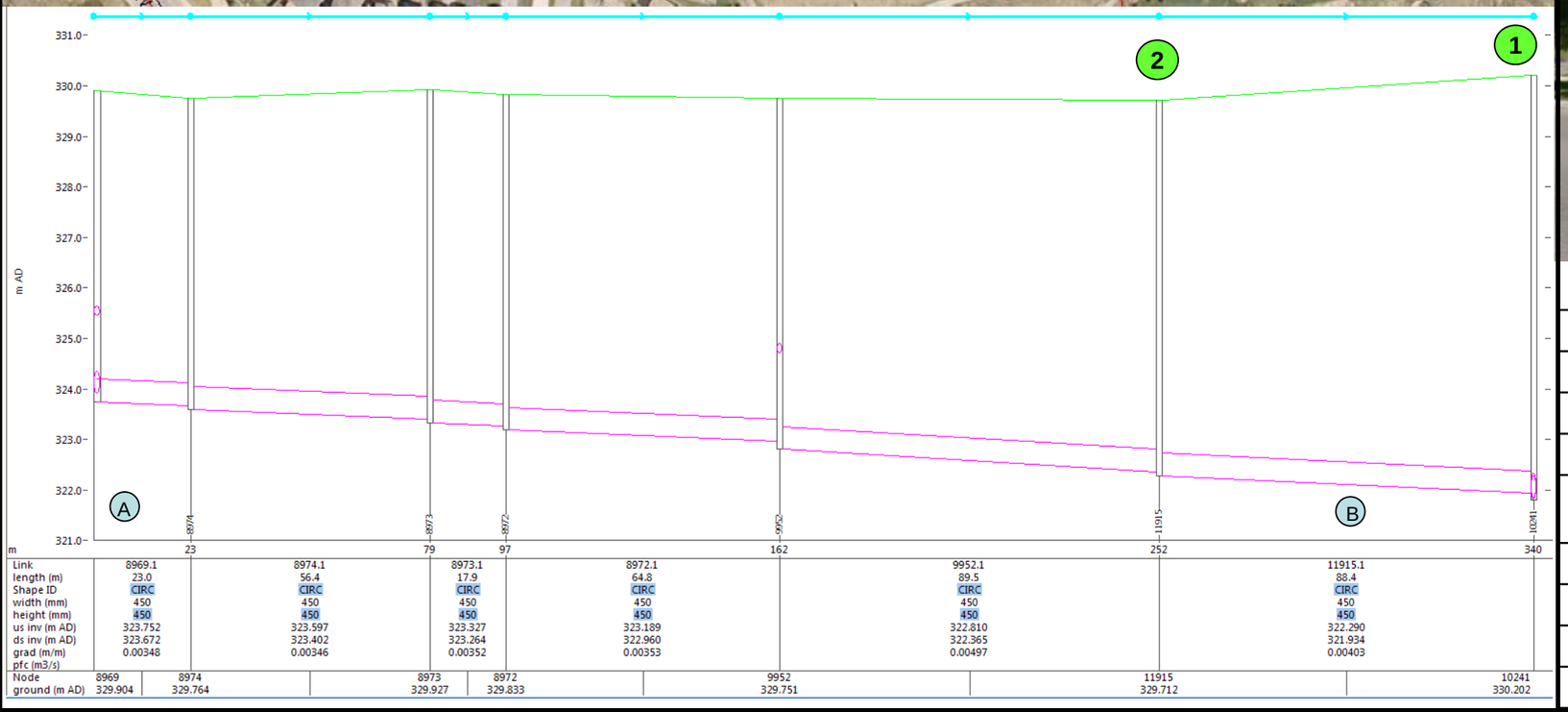
Figure: A5

Legend (Plan)

- Sanitary Sewer
- 1 Primary FM Candidate Site
- 2 Secondary FM Candidate Site
- A A Photo View Cross Section
- A B Extents of the Profile







Location Details

	Primary 1	Secondary 2
MH ID	NRL-6 (10241)	NRL-7 (11915)
Upstream Diameter (mm)	450	450
Upstream Slope (%)	0.403	0.497
Downstream Diameter (mm)	525	450
Downstream Slope (%)	0.501	0.403
Drainage Area (ha)	79	79
Depth to Bottom (m)	8.2	7.3
Accessibility	On Road	On Road

Stantec

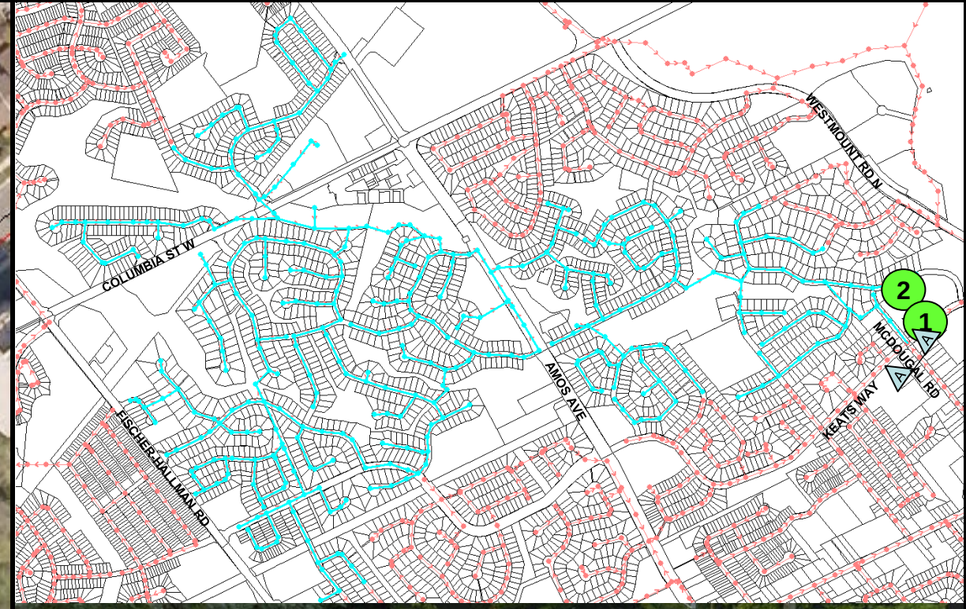
Waterloo Sanitary Master Plan Update

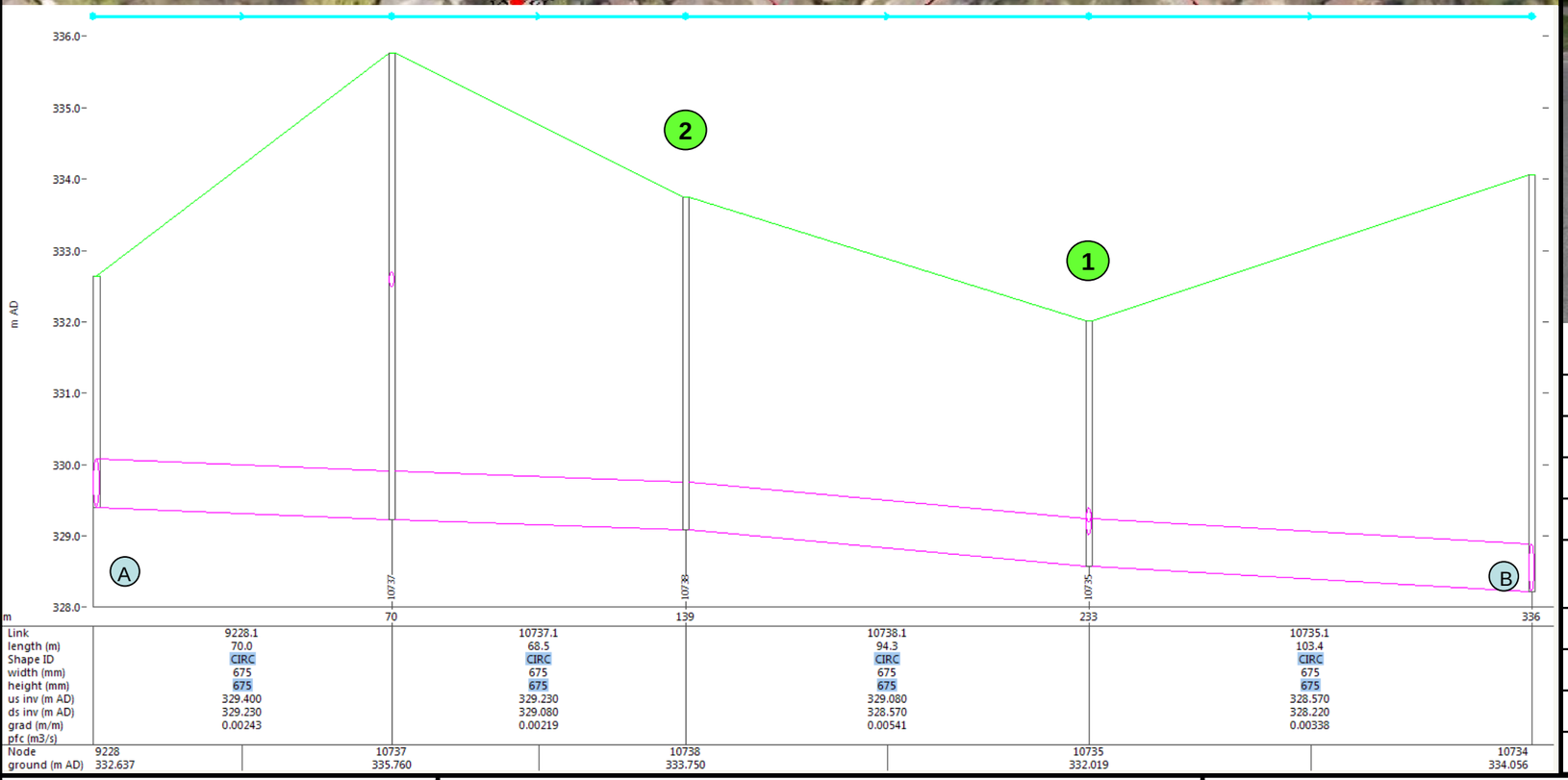
Monitor: NRL-6
Location: Upstream of Colonial SPS
Eastbridge Boulevard

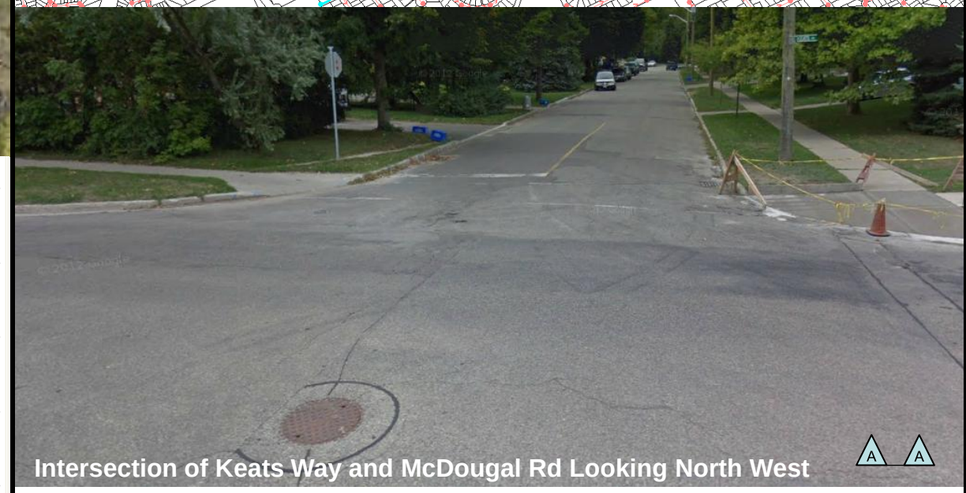
Scale: NTS

Date: March 2014

Figure: A6







Location Details

	Primary 1	Secondary 2
MH ID	KEA-5 (10735)	CLR-1 (10738)
Upstream Diameter (mm)	675	675
Upstream Slope (%)	0.541	0.243
Downstream Diameter (mm)	675	675
Downstream Slope (%)	0.338	0.541
Drainage Area (ha)	184	184
Depth to Bottom (m)	3.4	4.7
Accessibility	On Road	On Road

Stantec

Waterloo Sanitary Master Plan Update

Monitor: KEA-5
Location: The Clair Trunk
McDougal Rd at Keats Way

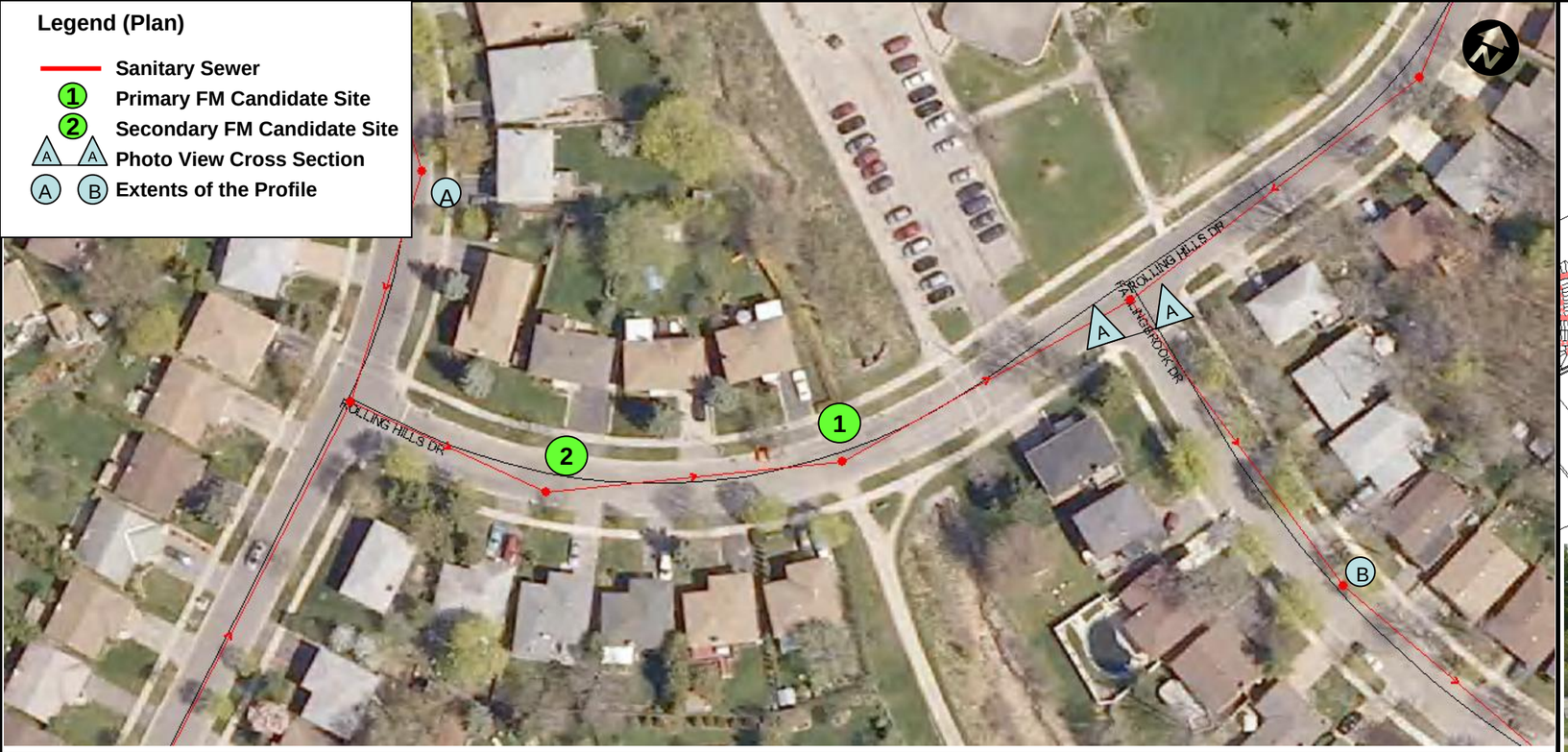
Scale: NTS

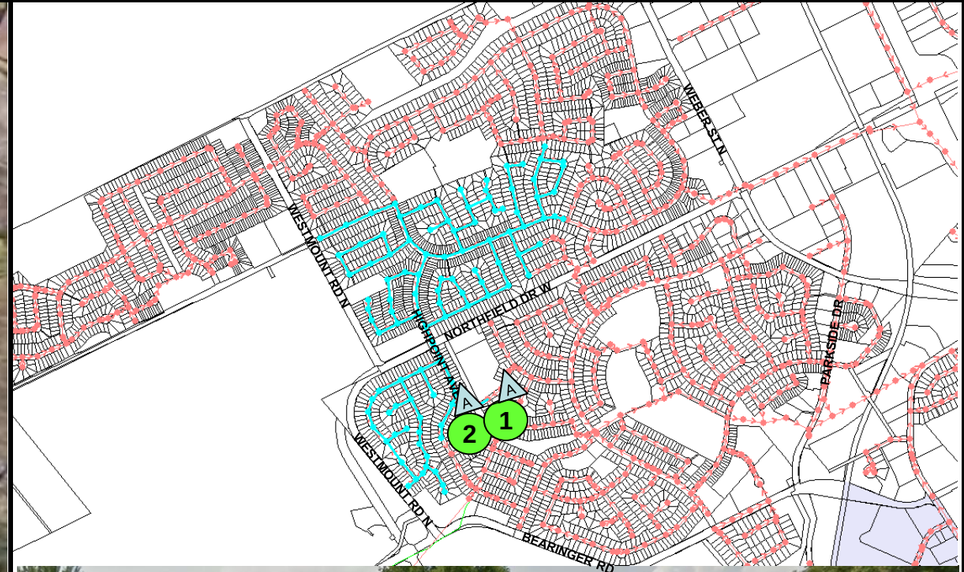
Date: March 2014

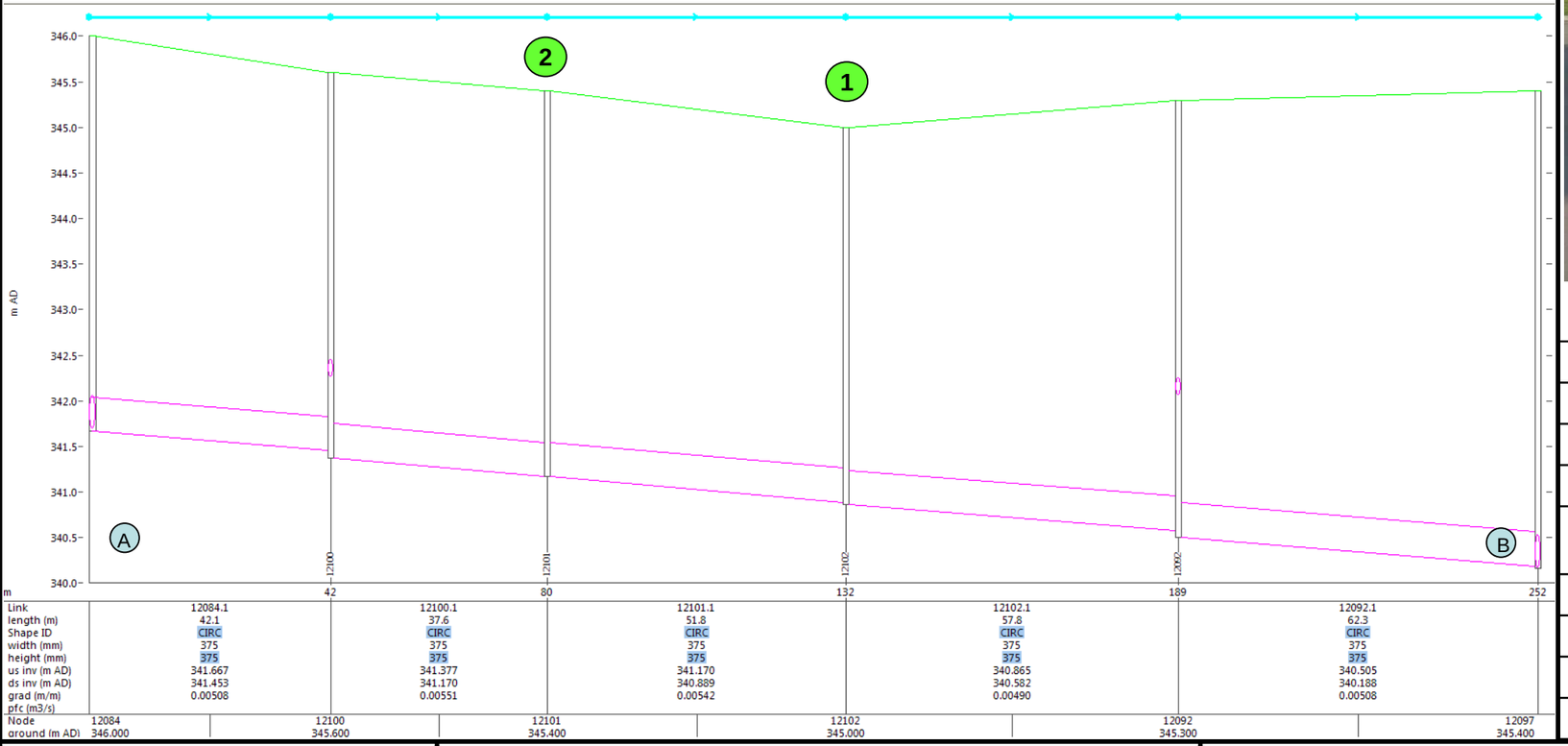
Figure: A7

Legend (Plan)

- Sanitary Sewer
- 1 Primary FM Candidate Site
- 2 Secondary FM Candidate Site
- A A Photo View Cross Section
- A B Extents of the Profile







Link	12084.1	12100.1	12101.1	12102.1	12092.1
length (m)	42.1	37.6	51.8	57.8	62.3
Shape ID	CIRC	CIRC	CIRC	CIRC	CIRC
width (mm)	375	375	375	375	375
height (mm)	375	375	375	375	375
us inv (m AD)	341.667	341.377	341.170	340.865	340.505
ds inv (m AD)	341.453	341.170	340.889	340.582	340.188
grad (m/m)	0.00508	0.00551	0.00542	0.00490	0.00508
pfc (m3/s)					
Node	12084	12100	12101	12102	12092	12097
ground (m AD)	346.000	345.600	345.400	345.000	345.300	345.400

Location Details

	Primary 1	Secondary 2
MH ID	C29-8 (12102)	C29-9 (12101)
Upstream Diameter (mm)	375	375
Upstream Slope (%)	0.542	0.551
Downstream Diameter (mm)	375	375
Downstream Slope (%)	0.490	0.542
Drainage Area (ha)	61	61
Depth to Bottom (m)	4.1	4.2
Accessibility	On Road	On Road

Stantec

Waterloo Sanitary Master Plan Update

Monitor: C29-8
Location: The Cedar Trunk
Rolling Hills Dr at Fallingbrook Drive

Scale: NTS

Date: March 2014

Figure: A8